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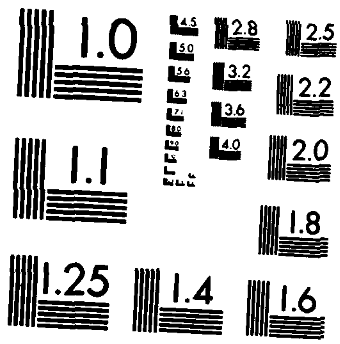

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THE WEAPONS SUPPORT SYSTEM GRAVITY DATA EVALUATION SOFTWARE PROGRAM DOCUMENTATION

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Douglas W. Capp

The Analytic Sciences Corporation
One Jacob Way
Reading, Massachusetts 01867

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
United States Air Force
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The purpose of this report is to provide documentation for the gravity data evaluation software, which was written by TASC for the Defense Mapping Agency as part of the Weapons Support System. Many of the mathematical techniques and algorithms are described. In this report the programs developed for gravity data evaluation are documented at a level suitable for use by programmers who will be adapting or modifying these programs. The report is intended for use in conjunction with the Weapons Support System User's Guide and relevant operating system (VAX/VMS) documentation.

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PREFACE

Documentation for the Weapons Support System (WSS), developed for the Defense Mapping Agency by The Analytic Sciences Corporation, consists of a User's Guide (TR-1946-1) that gives an overview of the WSS hardware and software, as well as detailed operating instructions for the major application areas listed below; and four volumes of detailed program documentation:

- Gravity Data Evaluation Software (TR-1946-2)
- Data Smoothing and Spectrum Analysis Programs (TR-1946-3)
- MULTISENSOR Simulation Software (TR-1946-4)
- GEOFAST Software Documentation (TR-1946-5)

This volume, Gravity Data Evaluation Software, documents the programs developed for use in the gravity data evaluation process, at a level suitable for use by programmers who will be adapting or modifying these programs. It is intended for use in conjunction with the Weapons Support System User's Guide and relevant operating system (VAX/VMS) documentation.

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1. PROGRAM OVERVIEW

1.1 INTRODUCTION

The purpose of this report is to provide documentation for the gravity data evaluation software, which was written by TASC for the Defense Mapping Agency as part of the Weapons Support System. Many of the mathematical techniques and algorithms described throughout this report are presented in Refs. 1 and 2.

1.2 GENERAL SOFTWARE OVERVIEW

The gravity data evaluation software is a collection of programs which are designed to assist the evaluator in the various tasks involved in the evaluation of gravity survey data. All of the programs are run interactively from one of the VT100 terminals. Many of the programs make extensive use of the Lexidata graphics terminal. These graphical plots provide the evaluator with a quick-look capability for making rapid decisions concerning the data. The programs also allow the user to obtain hard copies of the plots on the line printer.

The gravity data evaluation software section also includes the system file editing and manipulation utilities. These utilities will allow the user to perform various operations on data files or program source files. Two of the utilities which are especially useful in the evaluation of gravity data are the interactive text editor and the SORT/MERGE facility.

1.3 OUTLINE OF COMPUTER PROGRAMS

The gravity data evaluation software consists of seven main programs. A short description of each of the programs is given below.

- The program SCATTER is used to construct a scatter plot showing the geographic locations of the gravity stations
- The program CONPLOT is used to draw a contour plot of a specified data field
- The program SURPLOT draws a three-dimensional surface plot of a specified data field
- The program STATPLOT is used for robust estimation and statistical plotting.

The following three programs are part of the ocean-track crossing adjustment section of the gravity data evaluation software. These programs are specially designed for the evaluation of ocean gravity survey data.

- The program CLEANUP is used to remove extraneous points from an ocean track file
- The program SPLINE determines the free-air gravity anomaly value of an ocean track at an intersection point
- The program LINPRO computes the ocean track adjustments using a method based on linear programming.

1.4 DOCUMENT OVERVIEW

The gravity data evaluation programs are designed as part of the software of the Weapons Support System. The

programs are written to run under the VAX/VMS operating system. Users of these programs should refer to the VAX/VMS Reference Manuals for information regarding file structure and file naming conventions.

Section 2 of this report is a self-contained user's guide for the gravity data evaluation programs. The user's guide leads the user through the steps needed to run the different evaluation programs. The user's guide also describes the various plotting options which the user may invoke while running the gravity data evaluation software.

Section 3 provides detailed documentation for use by a programmer maintaining the gravity data evaluation software. It describes the organization of the different programs, the data structures used, and the calling sequence of upper-level subroutines. It also lists the names and functions of all subroutines used by the programs, and it describes some of the mathematical algorithms implemented by the various programs.

2. USER'S GUIDE FOR THE GRAVITY DATA EVALUATION SOFTWARE

2.1 OVERVIEW OF THE GRAVITY DATA EVALUATION CAPABILITIES

The gravity data evaluation software is a collection of tools designed to assist the evaluator in the various tasks involved in analyzing gravity survey data. These tasks include:

- Elimination of erroneous and redundant data
- Verification of gravity base stations
- Adjustment of systematic inconsistencies between sources
- Identification and correction of recoverable errors
- Assignment of accuracy measures to each source.

The various programs which make up the gravity data evaluation software make extensive use of the Lexidata graphics terminal. The graphical displays are extremely useful in that they provide the evaluator with a quick-look capability for making rapid decisions concerning the data. However, these programs also rely heavily on the evaluator's judgment and experience.

The gravity data evaluation software is divided into major sections. They are:

- The scatter plot program
- File editing and manipulation utilities
- The contour plot program
- The three-dimensional surface plot program
- Robust estimation and statistical plot program
- Ocean track-crossing adjustment programs

The Gravity Data Evalution User's Guide is organized in the following manner. The first section will describe the formatting requirements for the data files which will be processed by the gravity data evaluation programs. The next six sections will present detailed descriptions of how to implement the major sections of the gravity data evaluation software. The final section lists the error and warning messages which may occur during execution of the evaluation programs.

2.2 PREPROCESSING REQUIREMENTS

The Weapons Support System (WSS) uses two different data formats for storing and processing gravity survey data. First, the WSS can read and store data from the Department of Defense (DoD) Gravity Library in the standard 80 column card format. For ease of use, however, a subset of the 80 column card format is commonly used as input to the gravity data evaluation software. This data format is called the WSS online format.

One of the implications of using the two different data formats is that even if the 30 column card format should change, the WSS online format need not. However, the use of two data formats means that a utility program must be used to

convert from the card format to the WSS online format. This utility program, called REFORMAT, is included as part of the gravity data evaluation software. The program will first read the data stored in the 80 column card format. It will then allow the user to select subsets of the data based on:

- Geographic latitude/longitude boundaries
- Source identification number
- Any combination of the two.

The utility program will then create a data file containing the chosen subset of points in the WSS online format.

All of the programs which are part of the gravity data evaluation software use as input any file which is in the WSS online format. The WSS online format consists of the following data fields:

• Source number	
• Latitude	(decimal degrees)
• Longitude	(decimal degrees)
• Elevation	(meters)
• Observed gravity	(less 976,000 mgal)
• Free-air gravity anomaly	(mgal)
• Bouguer gravity anomaly	(mgal).

The file, in WSS online format, is read by the various programs using a formatted READ statement. The format for the READ statement is given by:

```
FORMAT(I5,2F10.4,F8.1,F8.2,2F7.1)
```

Before using any of the programs in the gravity data evaluation section, the user should make sure that the gravity file to be examined is in the WSS online format.

2.3 THE SCATTER PLOT PROGRAM

2.3.1 Purpose and Scope

The purpose of the scatter plot program is to display on the Lexidata graphics terminal the geographic locations of the gravity stations in a file containing gravity survey data. The scatter plot is superimposed on a map showing major political boundaries and coastlines. The map is drawn using a Mercator map projection. Both land and ocean gravity data can be displayed using this program, and multiple sources within the same region are distinguished using different letters of the alphabet. The program is also set up to invoke the cursor, which can be used to identify individual points or subsets of points. The scatter plot program is run interactively from one of the VT100 terminals, and it requires the user to respond to several prompts and menu selection options.

2.3.2 Program Limitations

Since the scatter plot program requires the use of the Lexidata graphics terminal, the user should make sure that the graphics terminal is available before running the program. The user should also make sure that all the toggle switches on the trackball unit are in the OFF position.

The scatter plot program handles files with up to 5000 points. Larger files should be separated into smaller subfiles before processing with the scatter plot program.

Since the program uses the letters of the alphabet to distinguish different sources, a maximum of 26 unique sources can be identified within a given region.

2.3.3 Running the Scatter Plot Program

To run the scatter plot program, the user types the following command:

```
RUN SCATTER
```

The user will then be prompted to enter the name of the file containing the gravity survey data to be examined. The file name must include all qualifiers to identify the file uniquely. A complete file specification has the following format:

```
device:[directory]filename.type;version
```

The punctuation marks (colons, brackets, periods, semi-colons) are required to separate the various components of the file specification. If the input file is on the same directory as the user, only the filename and type need to be specified. The default file type is DAT, and if no version number is given, the file with the highest version number is used. Volume 2A of the VAX/VMS Reference Manuals contains a complete description of file specification.

If the word QUIT is typed for the input file name, the scatter plot program will stop execution and return control to VMS. The user should note that if the word QUIT is typed for many of the input prompts, the program will terminate and return control to VMS.

After reading the gravity file, the program will prompt the user for several inputs regarding latitude and longitude limits for the plot, plot title, and whether the user wants grid lines on the plot. All of the prompts have default values, which the user can select by pressing only the RETURN key.

The scatter plot is drawn using letters of the alphabet to represent data points from different sources. The major political boundaries and coastlines which lie within the limits of the scatter plot are drawn in red, and the latitude and longitude grid lines are drawn in blue.

When the scatter plot is completed, the following menu will appear on the VT100 screen:

```
TYPE <CR> - TO ZOOM, SCROLL AND IDENTIFY
            POINTS WITH THE CURSOR
   Replot - TO CREATE NEW PLOT
    Print - TO GET A HARD COPY OF PLOT
     Quit - TO HALT PROGRAM EXECUTION
```

When an option is selected, only the first letter of the user's response is examined. Hence, typing any character string that starts with P will produce a hard copy of the plot. A description of each option will now be given.

<CR> - Typing the RETURN key will allow the user to zoom, scroll, and select points using the cursor. Further details will be presented below.

Replot - By typing Replot (or R), the user can create a new plot on the graphics terminal. The user will be prompted for new latitude and longitude limits, and a new title.

Print - Typing Print (or P) will cause the scatter plot on the graphics terminal to be printed on the line printer. The user will then be asked to select again from this same menu.

Quit - Typing Quit (or Q) will cause the program to terminate.

If the user selects the zoom, scroll, and point selection option, the VT100 terminal screen will clear, and a map legend, which lists the source numbers and corresponding letters of the alphabet, will appear. The following menu will then be displayed on the VT100 screen:

```
ENTER 1 - ZOOM AND SCROLL
      2 - USE CURSOR TO SELECT INDIVIDUAL POINTS
      3 - USE CURSOR TO SELECT POINTS WITHIN
              A RECTANGULAR REGION
      4 - USE CURSOR TO SELECT ENTIRE TRACKS
      5 - USE CURSOR TO IDENTIFY INTERSECTION POINTS
     99 - TO EXIT FROM THE PROGRAM
```

A description of each of the options will now be presented.

1 - By typing a 1, the user invokes the zoom and scroll option. By rolling the trackball, the user can move the scatter plot around the screen. To invoke the zoom feature, the user should move the area to be enlarged to the upper left corner of the graphics screen, and toggle the blue switch on the trackball unit. The user will then be prompted for the zoom factor at the VT100 terminal. The zoom factor is any integer value between 1 and 16. After the user enters the zoom level, the plot will be enlarged at the specified level. The program is still in the scroll mode, so that the picture can be moved about the screen. The blue switch can be toggled again, to enter a different zoom level. To freeze the screen and terminate the zoom and scroll option, the user should toggle switch A (i.e., the left-most white switch) on the trackball unit.

2 - Typing a 2 will invoke the cursor on the graphics terminal and allow the user to select individual points. To select a point, the user moves the cursor with the trackball over a point, and toggles the blue switch. The selected point will be marked in red. If there are several points near the cursor, the program will select the point nearest to the center of the cursor. The record in the gravity file corresponding to the selected point will be displayed at the VT100 terminal. The user will then have the option of saving the point in a separate file. Additional points can then be identified by moving the cursor and toggling the blue switch. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

3 - Typing a 3 will allow the user to select all points within a rectangular region on the scatter plot. Using the trackball, the user moves the cursor to one corner of the desired region and toggles the blue switch. A red "+" will appear on the graphics terminal. The user then moves the cursor to the diagonally opposite corner of the region, and again toggles the blue switch. Another "+" will appear at the point, and the rectangular region will be drawn using the two marked points. The points within the region will be marked in red, and a listing of the records of all the selected points will be displayed on the VT100 screen. The user will have the option of saving these points in a separate file. More regions can then be drawn by repeating the same steps. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

4 - Typing a 4 will allow the user to select entire tracks of data. This feature is most useful when analyzing ocean data, where the data tend to lie along tracks. As in selecting points within a rectangular region, the user employs the cursor to mark the beginning and ending points of the track. The selected points will be marked in red, and they will also be

listed at the VT100 terminal. The user will have the option of saving them. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

5 - Typing a 5 will allow the user to determine the coordinates of track intersection points. Again, this is most useful when analyzing ocean data. The user should move the cursor over the intersection point and toggle the blue switch. The latitude and longitude coordinates of the intersection point will appear on the VT100 screen. Further intersection points can then be determined. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

99 - Typing a 99 will cause the program to terminate.

Note that for each of the user-selected options, the user terminates an option by toggling switch A. The user menu selection options will then appear on the screen. Before selecting another option, the user should make sure that switch A is in the OFF position.

If an invalid switch is toggled during execution of any of the user selected options, the following message will appear on the screen:

```
***** USER ERROR *****
AN INVALID SWITCH HAS BEEN TOGGLED
RESET TOGGLE SWITCH AND TRY AGAIN
```

The user should move the invalid switch to the OFF position before toggling the correct switch.

2.4. FILE EDITING AND MANIPULATION UTILITIES

2.4.1 Introduction

The VAX/VMS operating system has an extensive set of commands for editing and manipulating data files and user programs. These commands are part of the Digital Command Language (DCL). The DCL command language contains commands for performing such operations as:

- Changing and/or modifying files
- Printing files on the line printer
- Deleting one or more files
- Copying sections of one file into another file
- Sorting files on specified fields.

The various DCL commands are fully documented in Volume 2A of the VAX/VMS Reference Manuals. The documentation is also available at the VT100 terminal by use of the HELP command. To invoke the HELP command, the user simply types the word HELP, followed by the command for which more information is required. The HELP command will respond with a summary of the format of the particular command or a list of the command's valid qualifiers. For example, to obtain more information about the COPY command, the user should type:

```
HELP COPY
```

The system responds by displaying at the terminal a summary of the COPY command and keywords to enter as parameters to the HELP command to obtain additional information. As an example, if the user types:

HELP COPY/EXTENSION

the system will respond with information concerning the extensions to be added to the output file. If the user enters:

HELP COPY QUALIFIERS

the HELP command will display a description of each of the COPY command qualifiers.

Two of the file manipulation utilities which are used very frequently are the interactive text editor and the sorting facility. A description of these two utilities will now be presented.

2.4.2 Interactive Text Editor

The interactive text editor allows the user to examine, create, and/or modify data files or user programs from the VT100 terminal. The VAX/VMS operating system has two interactive text editors. They are called SOS and EDT. The SOS editor is a line editor, while the EDT editor is a full-screen editor. The EDT editor is the more useful of the two. Complete documentation for both of these editors is given in Volume 3A of the VAX/VMS Reference Manuals.

The easiest way to learn how to use the EDT editor is to run the EDT Editor Computer Aided Instruction minicourse, which is called EDTCAI. This minicourse is presented interactively at the computer terminal. The computer will display information about the EDT editor on the VT100 terminal screen, allow the user to practice entering EDT commands, and ask the user questions about what has been learned. For more information about running EDTCAI, the user should talk to the systems manager.

2.4.3 SORT/MERGE Facility

The SORT/MERGE facility allows users of the VAX/VMS operating system to reorder data files in either ascending or descending order. The user can sort several files using the same field, and then merge the files into one sorted file. The user can run SORT/MERGE interactively from the terminal, as a batch job, or as part of a user program.

The purpose of this section is to present a brief introduction to some of the useful capabilities of the SORT/MERGE facilities. The user should refer to Volume 3A of the VAX/VMS Reference Manuals for a detailed description of the various features in the SORT/MERGE program.

The SORT command has the following general form:

```
SORT/KEY=([qualifiers]) input-file(s) output-file
```

The qualifiers specify which data field is to be used as the sort key. The user can specify up to 10 different input files, which must exist either on the disk or magnetic tape. The output file contains the sorted records.

For example, assume that the user has a WSS gravity input file called SRCE4242.DAT. (See section 2.2 for a description of the WSS online file format). To sort this file on the elevation field, the user types:

```
SORT/KEY=(POSITION=26,SIZE=8) SRCE4242.DAT SORT.DAT
```

The output file, SORT.DAT, will contain all the records of the file SRCE4242.DAT sorted by elevation in ascending order.

If more than one input file is specified, the input files will all be sorted on the specified field, and then merged into a single sorted file. This could be used to facilitate a Common Station Compare. For example, if the user has two files of gravity survey data covering the same region, FILE1.DAT and FILE2.DAT, then the following command:

```
SORT/KEY=(POS=6,SIZE=10)/KEY=(POS=16,SIZE=10) -
     FILE1.DAT,FILE2.DAT  COMMON.DAT
```

will first sort the two input files by latitude and longitude, and then merge the two sorted files into COMMON.DAT. Hence, pairs of points which are geographically close to each other will appear as sequential records in the output file.

Similarly, if several data files have already been sorted on the same field, they can be merged into a single sorted file using the MERGE command. The user should look in the reference manual for details on the MERGE command.

2.5 THE CONTOUR PLOT PROGRAM

2.5.1 Purpose and Scope

The purpose of the contour plot program is to display on the Lexidata graphics terminal a contour plot of a specified data field from a file containing gravity survey data. The program is set up to overlay the contour plot with a scatter plot, which shows the geographic locations of the individual gravity stations of the gravity survey file. Both land and ocean gravity data can be displayed using this program, and the data need not be evenly spaced. The program is also set up to invoke the cursor to identify individual points or subsets of points. The contour plot program is run interactively

from one of the VT100 terminals, and it requires the user to respond to several prompts and menu selection options. A sample of such a plot is provided in Fig. 2.5-1.

2.5.2 Program Limitations

Since the contour plot program requires the use of the Lexidata graphics terminal, the user should make sure that the graphics terminal is available before running the program. Also, the user should make sure that all the toggle switches located on the trackball unit are in the OFF position.

The contour plot program handles files with up to 5000 points. Larger files should be separated into smaller subfiles before processing with the contour plot program. The contour plot program also requires a minimum of two data points. However, to ensure that the contour plot adequately represents the data field, the file should contain at least 10 data points.

2.5.3 Running the Contour Plot Program

To run the contour plot program, the user types the following command:

```
RUN CONPLOT
```

The user will then be prompted to enter the file name containing the gravity survey data to be examined. The file name must include all qualifiers to identify the file uniquely. A complete file specification has the following format:

```
device:[directory]filename.type;version
```

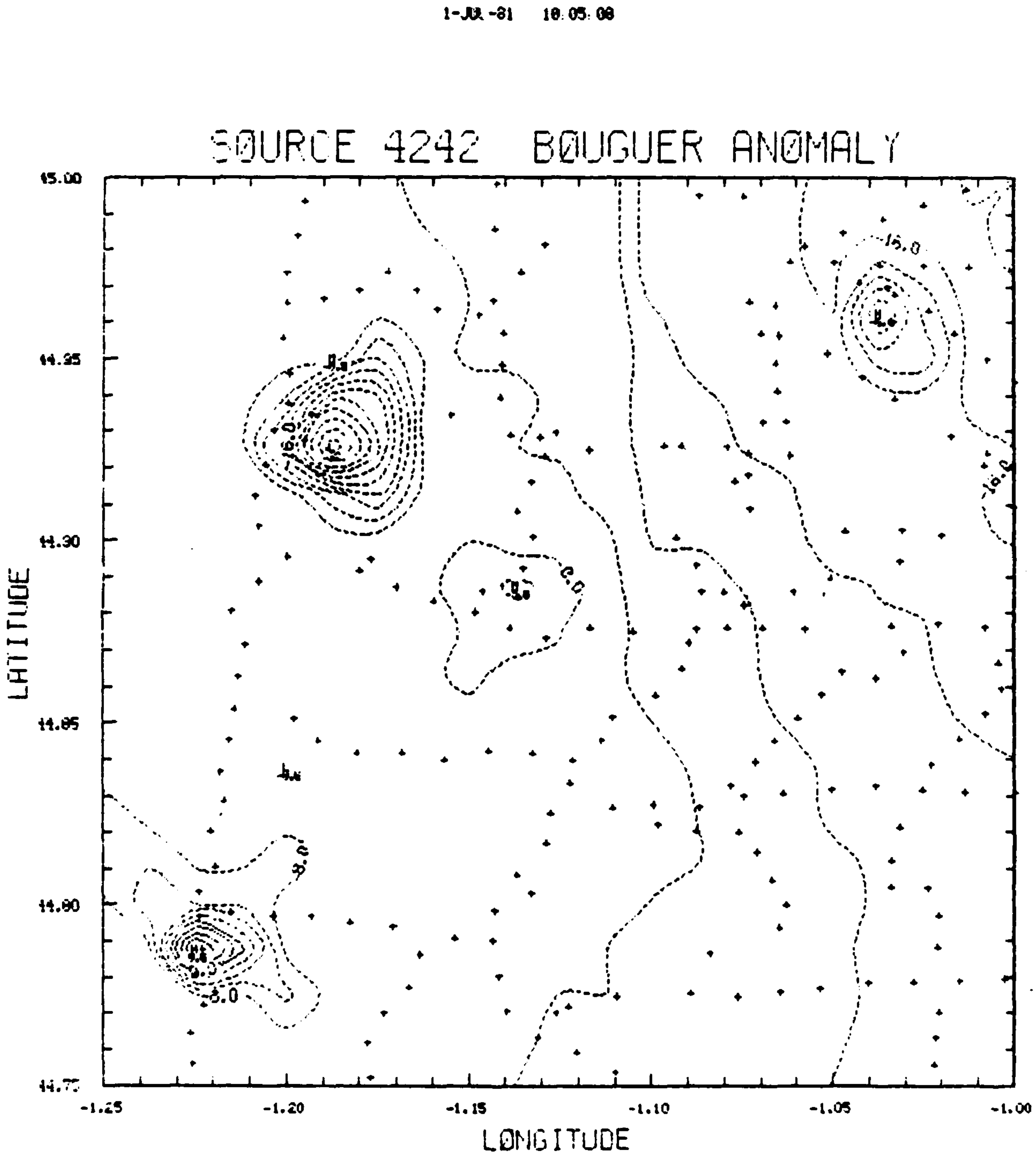

Figure 2.5-1 Typical Contour Plot

The punctuation marks (colons, brackets, periods, semi-colons) are required to separate the various components of the file specification. If the input gravity file is located on the same directory as the user, only the filename and type need to be specified. The default type is DAT, and if no version number is specified, then the file with the highest version number is used. Volume 2A of the VAX/VMS documentation contains a complete description of file specification.

If the word QUIT is typed for the input file name, the contour plot program will stop execution and return control to VMS. The user should note that if the word QUIT is typed for many of the input prompts, the program will terminate and return control to VMS.

After reading the gravity file, the program will prompt the user for inputs regarding latitude and longitude limits for the contour plot. All of the prompts have default values, which the user can select by pressing the RETURN key.

The user will then receive the following message at the terminal:

```
WHAT TYPE OF CONTOUR PLOT?
TYPE 1-ELEVATION PLOT
     2-FREE-AIR ANOMALY PLOT
     3-BOUGUER ANOMALY PLOT
```

The default value is a contour plot of the Bouguer gravity anomaly field. The user can select the default by pressing just the RETURN key.

The user is then requested to enter a title for the plot. The default title is the input file name, but the user may also wish to specify the field being contoured. That is,

a more useful title may be something like SOURCE 4242 BOUGUER ANOMALY. The plot title must be less than 40 characters.

The following message will then appear on the screen:

```
DO YOU WISH TO SELECT YOUR OWN CONTOUR LEVELS ?
ENTER Yes OR No
DEFAULT - No : LET PROGRAM CHOOSE "NICE" CONTOUR LEVELS
```

If the user selects the default option, the program will select the contour levels to be drawn. The program will select between 10 and 30 evenly spaced contour levels which will cover the range of data values.

The user can specify the contour levels by typing YES in response to the above prompt. If this option is selected, the user will be prompted for a minimum contour level, a maximum contour level, and the increment between the contour levels. The user can specify the value 0.0 for the increment value. This will cause the program to choose between 10 and 30 contour levels which lie between the maximum and minimum.

The contour plot is drawn so that the major contour levels are in green and the minor contour levels are in red. Positive contour levels are drawn as solid lines, while negative contours are drawn as dashed lines. Local minimum and maximum are labeled on the contour plot with an L and H, respectively. The geographic locations of the actual data points are marked on the plot with blue "+"s.

When the contour plot is completed, the following menu will appear on the VT100 screen:

```
TYPE <CR> - TO ZOOM, SCROLL AND IDENTIFY
            POINTS WITH THE CURSOR
   Replot - TO CREATE NEW PLOT
    Print - TO GET A HARD COPY OF PLOT
     Quit - TO HALT PROGRAM EXECUTION
```

When an option is selected, only the first letter of the user's response is examined. Hence, typing any character string that starts with P will produce a hard copy of the plot. A description of each option will now be given:

<CR> - Typing the RETURN key will allow the user to zoom, scroll, and select points using the cursor. Further details will be presented next.

Replot - By typing Replot (or R), the user can create a new plot on the graphics terminal. The user will be prompted for new latitude and longitude limits, a different data field, a new title, and new contour levels. As before, default values are available for the various prompts.

Print - Typing Print (or P) will cause the contour plot on the graphics terminal to be printed on the line printer. The user will then be asked to select again from this same menu.

Quit - Typing Quit (or Q) will cause the program to terminate.

If the user selects the zoom, scroll, and point selection option, the following menu will appear on the screen:

```
ENTER 1 - ZOOM AND SCROLL
      2 - USE CURSOR TO SELECT INDIVIDUAL POINTS
      3 - USE CURSOR TO SELECT POINTS WITHIN
              A RECTANGULAR REGION
      4 - NEW PLOT
     99 - TO EXIT FROM THE PROGRAM
```

A decription of each of the options will now be presented.

1 - By typing a 1, the user invokes the zoom and scroll option. By rolling the trackball, the user can move the contour plot around the screen. To invoke the zoom feature, the user should move the area to be enlarged to the upper left corner of the graphics screen, and toggle the blue switch on the trackball unit. The user will then be prompted for the zoom factor at the VT100 terminal. The zoom factor is any integer value between 1 and 16. After the user enters the zoom level, the plot will be enlarged at the specified level. The program is still in the scroll mode, so that the picture can be moved about the screen. The blue switch can be toggled again, to enter a different zoom level. To freeze the screen and terminate the zoom and scroll option, the user should toggle switch A (i.e., the left-most white switch) on the trackball unit.

2 - Typing a 2 will invoke the cursor on the graphics terminal and allow the user to select individual points. To select a point, the user moves the cursor with the trackball over a point, and toggles the blue switch. The selected point will be marked in red. If there are several points near the cursor, the program will select the point nearest to the center of the cursor. The record in the gravity file corresponding to the selected point will be displayed at the VT100 terminal. The user will then have the option of saving the point in a separate file. Additional points can then be identified by moving the cursor and toggling the blue switch. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

3 - Typing a 3 will allow the user to select all points within a rectangular region on the contour plot. Using the trackball, the user moves the cursor to one corner of the desired region and toggles the blue switch. A red "+" will appear on the graphics terminal. The user then moves the cursor to the diagonally opposite corner of the region, and again toggles the blue switch.

Another "+" will appear at the point, and the rectangular region will be drawn using the two marked points. The points within the region will be marked in red, and a listing of the records of all the selected points will be displayed on the VT100 screen. The user will have the option of saving these points in a separate file. More regions can then be drawn by repeating the same steps. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

4 - By typing a 4, the user can create a new contour plot on the graphics terminal. The user will be prompted for new latitude and longitude limits, a different data field, a new title, and new contour levels. As before, default values are available for the various prompts.

99 - Typing a 99 will cause the program to terminate.

Note that for each of the user-selected options, the user terminates an option by toggling switch A. The user menu selection options will then appear on the screen. Before selecting another option, the user should make sure that switch A is in the OFF position.

If an invalid switch is toggled during execution of any of the user selected options, the following message will appear on the screen:

```
***** USER ERROR *****
AN INVALID SWITCH HAS BEEN TOGGLED
RESET TOGGLE SWITCH AND TRY AGAIN
```

The user should move the invalid switch to the OFF position before toggling the correct switch.

2.6. THE THREE-DIMENSIONAL SURFACE PLOT PROGRAM

2.6.1 Purpose and Scope

The purpose of the three-dimensional surface plot program is to display on the Lexidata graphics terminal a surface plot of a specified data field from a file containing gravity survey data. Both land and ocean gravity data can be displayed using this program, and the data need not be evenly spaced. The three-dimensional surface plot program is run interactively from one of the VT100 terminals, and it requires the user to respond to several prompts and menu selection options. A sample of such a surface plot is shown in Fig. 2.6-1.

2.6.2 Program Limitations

Since the surface plot program requires the use of the Lexidata graphics terminal, the user should make sure that the graphics terminal is available before running the program. The user should also make sure that all the toggle switches located on the trackball unit are in the OFF position.

The surface plot program handles files with up to 5000 points. Larger files should be separated into smaller subfiles before processing with the surface plot program. The surface plot program also requires a minimum of two data points. However, to ensure that the surface plot adequately represents the data field, the file should contain at least 10 data points.

2.6.3 Running the Three-Dimensional Surface Plot Program

To run the surface plot program, the user types the following command:

1-JUL-81 10:13:08

SOURCE 4242

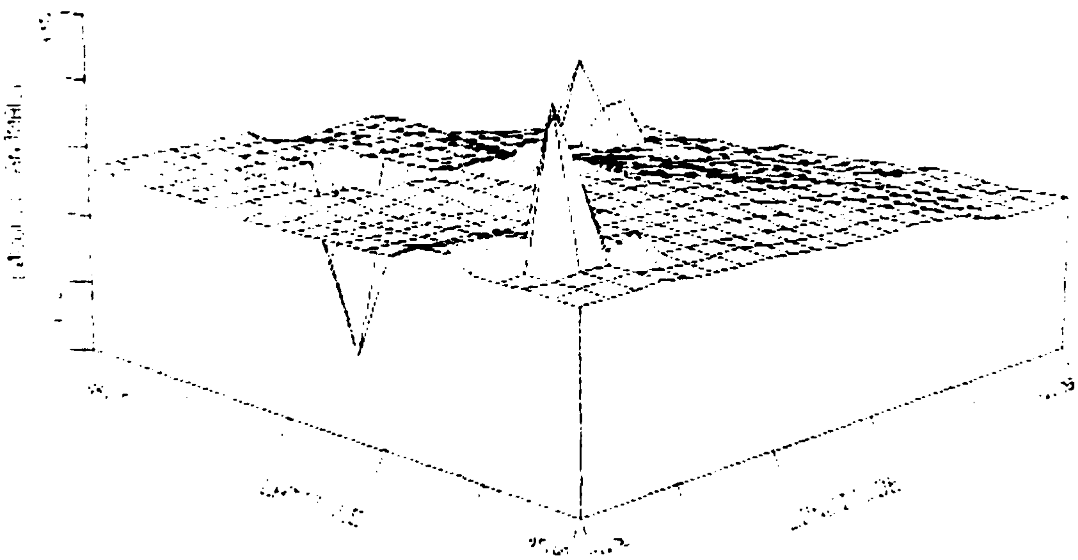

Figure 2.6-1 Typical Surface Plot

RUN SURPLOT

The user will then be prompted to enter the file name containing the gravity survey data that are to be examined. The file name must include all qualifiers to identify the file uniquely. A complete file specification has the following format:

device:[directory]filename.type;version

The punctuation marks (colons, brackets, periods, semi-colons) are required to separate the various components of the file specification. If the input gravity file is located on the same directory as the user, only the filename and type need to be specified. The default type is DAT, and if no version number is specified, the file with the highest version number is used. Volume 2A of the VAX/VMS Reference Manuals contains a complete description of file specification.

If the word QUIT is typed for the input file name, the surface plot program will stop execution and return control to VMS. The user should note that if the word QUIT is typed for many of the input prompts, the program will terminate and return control to VMS.

After reading the gravity file, the program will prompt the user for inputs regarding latitude and longitude limits for the surface plot. All of the prompts have default values, which the user can select by pressing the RETURN key.

The user will then receive the following message at the terminal:

```
WHAT TYPE OF SURFACE PLOT?
TYPE 1 - ELEVATION PLOT
     2 - FREE-AIR ANOMALY PLOT
     3 - BOUGUER ANOMALY PLOT
```

The default value is a surface plot of the Bouguer gravity anomaly field. The user can select the default by pressing the RETURN key.

The user is then requested to enter a title for the plot. The default title is the input file name, but the user may change the title to any character string (maximum length of 40 characters).

The following message will then appear on the VT100 screen:

```
ENTER THE TWO VIEWING ANGLES FOR THE LINE OF SIGHT
    ANGH : ANGLE (DEGREES) IN THE X-Y PLANE TO THE LINE
           OF SIGHT (COUNTERCLOCKWISE FROM THE POSITIVE
           X-AXIS)
    ANGV : ANGLE (DEGREES) FROM THE X-Y PLANE TO THE
           LINE OF SIGHT.  POSITIVE ANGLES ARE ABOVE
           THE PLANE Z=0; NEGATIVE, BELOW.
```

For the surface plot program, the longitude scale is considered as the x-axis, and the latitude scale is the y-axis. The default values are 45 degrees for ANGH and 15 degrees for ANGV. The default values can be selected by typing the RETURN key.

When the surface plot is completed, the following menu will appear on the VT100 screen:

```
TYPE <CR> - TO ZOOM, SCROLL AND CHANGE
            VIEWING ANGLE
   Replot - TO CREATE NEW PLOT
    Print - TO GET A HARD COPY OF PLOT
     Quit - TO HALT PROGRAM EXECUTION
```

When an option is selected, only the first letter of the user's response is examined. Hence, typing any character string that starts with P will produce a hard copy of the plot. A description of each option will now be given.

<CR> - Typing the RETURN key will allow the user to zoom, scroll, and change the viewing angle. Further details will be presented next.

Replot - By typing Replot (or R), the user can create a new plot on the graphics terminal. The user will be prompted for new latitude and longitude limits, a different data field, a new title, and new viewing angles. As before, default values are available for the various prompts.

Print - Typing Print (or P) will cause the surface plot on the graphics terminal to be printed on the line printer. The user will then be asked to select again from this same menu.

Quit - Typing Quit (or Q) will cause the program to terminate.

If the user selects the zoom, scroll, and change viewing angle option, the following menu will appear on the screen:

```
ENTER 1 - ZOOM AND SCROLL
      2 - CHANGE VIEWING ANGLE
      3 - NEW PLOT
     99 - TO EXIT FROM THE PROGRAM
```

A decription of each of the options will now be presented.

1 - By typing a 1, the user invokes the zoom and scroll option. By rolling the trackball, the user can move the surface plot around the screen. To invoke the zoom feature, the user should move the area to be enlarged to the upper left corner

of the graphics screen, and toggle the blue switch on the trackball. The user will then be prompted for the zoom factor at the VT100 terminal. The zoom factor is any integer value between 1 and 16. After the user enters the zoom level, the plot will be enlarged at the specified level. The program is still in the scroll mode, so that the picture can be moved about the screen. The blue switch can be toggled again, to enter a different zoom level. To freeze the screen and terminate the zoom and scroll option, the user should toggle switch A (i.e., the left-most white switch) on the trackball unit.

2 - Typing a 2 will prompt the user for different viewing angles. The current angles are now the default values, which the user may specify by typing the RETURN key. After the plot is redrawn, the first menu selection will appear on the screen.

3 - By typing a 3, the user can create a new surface plot on the graphics terminal. The user will be prompted for new latitude and longitude limits, a different data field, a new title, and new viewing angles. As before, default values are available for the various prompts.

99 - Typing a 99 will cause the program to terminate.

2.7 ROBUST ESTIMATION AND STATISTICAL PLOT PROGRAM

2.7.1 Purpose and Scope

The purpose of the statistical plot program is to display on the Lexidata graphics terminal both quantile-quantile (QQ) plots and empirical cumulative distribution function (ECDF) plots of a specified data field from a file

containing gravity survey data. The program also contains routines for performing robust estimations on the data displayed. The program can also invoke the cursor to identify individual points or subsets of points. The statistical plot program is run interactively from one of the VT100 terminals, and it requires the user to respond to several prompts and menu selection options.

2.7.2 Program Limitations

Since the statistical plot program requires the use of the Lexidata graphics terminal, the user should make sure that the graphics terminal is available before running the program. The user should also make sure that the switches located on the trackball unit are in the OFF position.

The statistical plot program handles files with up to 5000 points. The robust estimators can also handle the same amount of data, except for the Hodges-Lehmann estimate which is limited to 1000 points. Larger files should be separated into smaller subfiles before processing with this program.

2.7.3 Running the Statistical Plot Program

To run the statistical plot program, the user enters the following command:

```
RUN STATPLOT
```

The user will then be prompted to enter the file name containing the gravity survey data to be examined. The file name must include all qualifiers to identify the file uniquely. A complete file specification has the following format:

device:[directory]filename.type;version

The punctuation marks (colons, brackets, periods,semi-colons) are required to separate the various components of the file specification. If the input file is on the same directory as the user, only the filename and type need to be specified. The default file type is DAT, and if no version number is given, the file with the highest version number is used. Volume 2A of the VAX/VMS Reference Manuals contains a complete description of file specification.

If the word QUIT is typed for the input file name, the statistical plot program will stop execution and return control to VMS. The user should note that if the word QUIT is typed for many of the input prompts, the program will terminate and return control to VMS.

The program will first display the latitude and longitude limits of the input gravity survey file, along with the number of points in the file. The user will then be prompted for the type of plot with

```
WHAT TYPE OF PLOT?
TYPE 1 FOR QQ PLOT
     2 FOR ECDF PLOT
 CURRENT VALUE IS           1
*****ENTER NEW VALUE OR <CR>*****
```

The default, as shown, is the QQ plot. The following message will then appear on the screen:

```
WHAT VALUES PLOTTED?
ENTER 1 - ELEVATION
      2 - FREE-AIR ANOMALY
      3 - BOUGUER ANOMALY
 CURRENT VALUE IS  3
*****ENTER NEW VALUE OR <CR>*****
```

The default value is a plot of the Bouguer gravity anomaly data.

The user is then requested to enter a title for the plot. The default title is the input file name, but the user may change the title to any character string (maximum length of 40 characters).

After the selected plot is finished, the following menu will appear on the VT100 screen:

```
TYPE <CR> - TO ZOOM, SCROLL AND IDENTIFY
               POINTS WITH THE CURSOR
      New - TO CREATE NEW PLOT
    Print - TO GET A HARD COPY OF PLOT
   Robust - TO INVOKE ROBUST ESTIMATION ROUTINES
     Quit - TO HALT PROGRAM EXECUTION
```

When an option is selected, only the first letter of the user's response is examined. Hence, typing any character string that starts with P will produce a hard copy of the plot. A description of each option will now be given

<CR> - Typing the RETURN key will allow the user to zoom, scroll, and select points using the cursor. Further details will be presented next.

New - By typing New (or N), the user can create a new plot on the graphics terminal. The user will be prompted for the type of plot, and data field. As before, default values are available for the various input prompts.

Print - Typing Print (or P) will cause the statistical plot on the graphics terminal to be printed on the line printer. The user will then be asked to select again from this same menu.

Robust - Entering Robust (or R) will allow the user to perform the robust estimation techniques on the current set of plotted data. Further details on the robust estimators will be given later.

Quit - Typing Quit (or Q) will cause the program to terminate.

If the user selects the zoom, scroll, and point selection option, the following menu will appear on the VT100 screen:

```
ENTER 1 - ZOOM AND SCROLL
      2 - USE CURSOR TO SELECT INDIVIDUAL POINTS
      3 - USE CURSOR TO SELECT POINTS WITHIN
              A RECTANGULAR REGION
      4 - REMOVE SELECTED POINTS AND REPLOT
      5 - NEW PLOT
     99 - TO EXIT FROM THE PROGRAM
```

A decription of each of the options will now be presented.

1 - By typing a 1, the user invokes the zoom and scroll option. By rolling the trackball, the user can move the statistical plot around the screen. To invoke the zoom feature, the user should move the area to be enlarged to the upper left corner of the graphics screen, and toggle the blue switch on the trackball. The user will then be prompted for the zoom factor at the VT100 terminal. The zoom factor is any integer value between 1 and 16. After the user enters the zoom level, the plot will be enlarged at the specified level. The program is still in the scroll mode, so that the picture can be moved about the screen. The blue switch can be toggled again, to enter a different zoom

level. To freeze the screen and terminate the zoom and scroll option, the user should toggle switch A (i.e., the left-most white switch) on the trackball unit.

2 - Typing a 2 will invoke the cursor on the graphics terminal and allow the user to select individual points. To select a point, the user moves the cursor with the trackball over a point, and toggles the blue switch. The selected point will be marked in red. If there are several points near the cursor, the program will select the point nearest to the center of the cursor. The record in the gravity file corresponding to the selected point will be displayed at the VT100 terminal. The user will then have the option of saving the point in a separate file. Additional points can then be identified by moving the cursor and toggling the blue switch. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

3 - Typing a 3 will allow the user to select all points within a rectangular region on the statistical plot. Using the trackball, the user moves the cursor to one corner of the desired region and toggles the blue switch. A red "+" will appear on the graphics terminal. The user then moves the cursor to the diagonally opposite corner of the region, and again toggles the blue switch. Another "+" will appear at the point, and the rectangular region will be drawn using the two marked points. The points within the region will be marked in red, and a listing of the records of all the selected points will be displayed on the VT100 screen. The user will have the option of saving these points in a separate file. More regions can then be drawn by repeating the same steps. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

4 - Entering a 4 will remove the selected points (those marked in red) and replot the rest of the data using the same type of plot (i.e., either a QQ plot or ECDF

plot). The user will then be prompted with the first menu selection options.

5 - By typing a 5, the user can create a new plot on the graphics terminal. The user will be prompted for the type of plot and data field. All the data points from the input file will be used in constructing the new plot, not the subset of points that command 4 would plot.

99 - Typing a 99 will cause the program to terminate.

Note that for each of the user-selected options, the user terminates an option by toggling switch A. The user menu selection options will then appear on the screen. Before selecting another option, the user should make sure that switch A is in the OFF position.

If an invalid switch is toggled during execution of any of the user selected options, the following message will appear on the screen:

```
***** USER ERROR *****
AN INVALID SWITCH HAS BEEN TOGGLED
RESET TOGGLE SWITCH AND TRY AGAIN
```

The user should move the invalid switch to the OFF position before toggling the correct switch.

If the user selects the robust estimator option, a list of valid commands for the robust estimators, along with a brief description of their meaning, will appear on the VT100 screen. To invoke any of the robust estimator commands, the user must enter at least the first three letters of the command name. The list includes the following commands:

DONE - The user will be returned to the user-selection options menu shown above.

QUIT - Program execution is terminated.

HELP - A list of valid commands is displayed with a brief explanation of what they do. This is the same list presented on entry to the robust estimator section.

MEAN - The mean and standard deviation of the plotted points are computed and displayed on the VT100.

BICKEL - The Bickel-Hodges estimate of the plotted points is computed and displayed on the VT100.

MEDIAN - The median, extremes, and the upper and lower quartiles are displayed on the VT100.

HODGES - The Hodges-Lehmann estimate of the plotted points is computed and presented on the VT100. Since this estimation technique computes the median of all possible pairs of values, it is limited to working on sets of data with less than 1000 points. In addition, if the number of points is large, it may take a long time to compute the estimate.

WINSOR - A Winsorized mean of the displayed data is computed and presented on the VT100. The user will be prompted to enter the percentage, which must be between 0 and 50 percent. The value is entered as a percent (e.g., ten percent is entered as a 10). The default percentage is what was used the last time, with 10 percent as the first default.

TRIMMED - The trimmed mean of the plotted points is computed and displayed on the VT100. The user will be prompted to enter the percentage, which must lie between 0 and 50 percent. The value is entered

as a percent (e.g., ten percent is entered as a 10). The default percentage is what was used the last time, with 10 percent as the first default.

ADAPTIVE - An adaptive trimmed mean of the plotted points is computed and presented on the VT100.

BIWEIGHT - The biweight estimate for the plotted points is computed and displayed on the VT100. The user will be prompted to enter the weighting factor, which must lie between 2 and 15. The default value is determined from the last use, with 5 being the first default.

FLATLABS - The least absolute value with flattened weights of the displayed data is computed and displayed on the VT100.

M-ESTIMATE - The M-estimate (type 1 or 2) is computed for the plotted points. The user will be prompted to enter the type, with the default being the last type used. The original default is type 1.

SINE-ESTIMATE - The sine estimate of the plotted points is computed and presented on the VT100.

After the user enters a RETURN (<CR>), the screen will clear, and the list of available commands will appear at the top of the screen, without any description. The number of points being analyzed by the robust estimator functions will also be displayed. The user can now enter any valid robust estimator command, and the results will be displayed on the VT100 screen. If there are fewer than 3 data points, some of the estimators will not function properly. Warning messages will be displayed if such cases arise. Further information on the robust estimators is given in Refs. 5 and 6.

2.8 OCEAN TRACK-CROSSING ADJUSTMENT PROGRAMS

2.8.1 Purpose and Scope

The purpose of the ocean track-crossing adjustment programs is to provide the user with a set of tools to aid in the evaluation of ocean gravity data. The evaluation of ocean data presents specific problems not encountered with land data. Gravity measurements in ocean areas are generally made along intersecting tracks, with large in-between areas in which no data are available.

One of the evaluation tasks specifically associated with ocean data is the determination and, if possible, adjustment of the systematic discrepancies at crossings of tracks belonging to different sources. The track adjustment process typically begins with a track of known (or assumed) high accuracy, or a track tied reliably to ground data (dockside calibration). The adjustments then work outward in cantilever style from the track or tracks assumed correct. The process as it is carried out in practice has subjective elements and is known to lead to different results in the hands of different evaluators.

An alternative approach to the track adjustment problem is to consider all tracks and intersection points within a given region simultaneously, and determine track adjustment factors on a global scale. The track adjustment problem can then be formulated as a linear programming model. The solution to the linear program is a set of track adjustments which minimize the maximum absolute discrepancy at the intersection points, subject to any constraints which the user may impose on the individual track adjustments. A detailed description of this method is given in Refs. 5 and 6.

Solving the ocean track-crossing adjustment problem consists of four major steps, which can be summarized as follows:

- Selection of individual tracks
- Determination of track intersection points
- Determination of gravity anomaly at the intersection points
- Setting up and solving the linear programming model.

To accomplish these four steps, the user must run four different programs. However, the four programs do not correspond exactly with the four major steps for solving the track-crossing adjustment problem. A description of each of these programs will be presented in Section 2.8.3. Section 2.8.4 will then describe how to combine these four programs in an organized manner to complete the four steps in solving the ocean track-crossing adjustment problem.

2.8.2 Program Limitations

The scatter plot program, which is one of the ocean track-crossing adjustment programs, requires the use of the Lexidata graphics terminal. The user should make sure that the graphics terminal is available before running the scatter plot program. The user should also make sure that all the toggle switches located on the trackball unit are in the OFF position.

The ocean track-crossing adjustment programs are able to handle files with up to 5000 points. Larger files should be separated into smaller subfiles before processing with the ocean track-crossing adjustment programs. The program which

sets up and solves the linear program can process a maximum of 25 tracks and 50 intersection points.

2.8.3 Ocean Track-Crossing Adjustment Program Descriptions

This section will present a description of the four programs which make up the ocean track-crossing adjustment software.

Program SCATTER

Program SCATTER produces a scatter plot of a selected file of ocean gravity data. This program is part of the gravity data evaluation software and has its own user's guide. The user should read the scatter plot user's guide (Sec. 2.3) before using program SCATTER with ocean data. Two of the features of the scatter plot program specifically designed for ocean data will now be discussed in detail.

When the scatter plot is completed and the user has selected the zoom, scroll, and point selection option, the following menu will appear on the VT100 screen:

```
ENTER 1 - ZOOM AND SCROLL
      2 - USE CURSOR TO SELECT INDIVIDUAL POINTS
      3 - USE CURSOR TO SELECT POINTS WITHIN
              A RECTANGULAR REGION
      4 - USE CURSOR TO SELECT ENTIRE TRACKS
      5 - USE CURSOR TO IDENTIFY INTERSECTION POINTS
     99 - TO EXIT FROM THE PROGRAM
```

Options 4 and 5 are specifically related to ocean data analysis, so a detailed description of these options will be presented here again.

4 - Typing a 4 will allow the user to select entire tracks of data. The user should use the cursor to mark the starting and stopping points of the track. The selected points will be marked in red, and the user will have the option to save them. Two problems can arise in selecting a track in this manner. First, because of the algorithm used to select the points along a track, the program may select points from other tracks at the intersection points. The user should still write all the selected points to a file. The extraneous points will be removed in another program. The second problem in selecting tracks by straight lines is that real data hardly ever occur along perfectly straight lines. One technique which avoids this problem is to divide the track into a few linear segments. Select the points in each segment using the cursor, and write the points from each segment into the same file. To terminate the track selection option, the user should toggle switch A (i.e., the left-most white switch).

5 - Typing a 5 will allow the user to identify track intersection points. To identify an intersection point, the user should move the cursor over the intersection point and toggle the blue switch. The latitude and longitude coordinates of the point will appear on the VT100 screen. Other intersection points can then be identified. To terminate this option, the user should toggle switch A (i.e., the left-most white switch).

The other options of the scatter plot are also available to the user for the analysis of ocean data. The scatter plot user's guide (Sec. 2.3) describes in detail how to use the other options.

Program CLEANUP

The purpose of the program CLEANUP is to remove the extra points which are sometimes selected as part of an ocean

track and to sort the track by latitude and longitude. To run the CLEANUP program, the user should type:

RUN CLEANUP

The user will then receive the following prompt at the terminal:

```
ENTER INPUT FILE NAME OR
      QUIT TO HALT PROGRAM EXECUTION
```

The user should respond with the name of one of the files containing points selected as lying along a track. If the word QUIT is typed for the input file name, the program will stop execution and return control VMS.

After the file name is entered and the track file is read, the VT100 terminal screen will clear, and a list of all the source numbers which occur in the file will be displayed, along with the number of points associated with each source number. The user will then receive the following prompt at the terminal:

```
ENTER SOURCE NUMBER OF RECORDS TO BE SAVED
ENTER A SOURCE NUMBER <0 TO TERMINATE PROGRAM
```

The user should respond with the source number of the points to be kept in the file. Points with a different source number will be deleted from the file. The user should note that the word QUIT is not an acceptable response to this prompt. To terminate the program, the user should enter a negative number for the source number.

The program will create a new file with the same name as the input file. The new file will contain only those points

with the specified source number, and the records in the file will be sorted by latitude and longitude. The original file will still exist on the disk.

Program SPLINE

The purpose of program SPLINE is to compute the value of the free-air gravity anomaly along a track at an intersection point. In order for this program to function properly, the user must first run CLEANUP. To run the SPLINE program, the user should type:

```
RUN SPLINE
```

A message will appear on the screen warning the user to run CLEANUP before using program SPLINE. Next, the user will receive the following prompt at the terminal:

```
ENTER INPUT FILE NAME OR
      QUIT TO HALT PROGRAM EXECUTION
```

The user should repond with the name of a file containing track data processed by the program CLEANUP. If the word QUIT is typed for the input file name, the program will stop execution and return control to VMS. The user should note that if the word QUIT is typed for many of the input prompts, the program will terminate and return control to VMS.

Next, the user will receive the following prompt at the terminal:

```
ENTER LATITUDE AND LONGITUDE OF INTERSECTION PONT
ENTER A VALUE > 90 FOR THE LATITUDE
      TO TERMINATE THE PROGRAM
```

The user should note that the word QUIT is not an acceptable response for this prompt. To terminate the program, the user should enter a value larger than 90 for the latitude.

After the user enters values for the latitude and longitude, the program will echo the values and ask if they are correct. In case of an error, the user can reenter different values for latitude and longitude. If the latitude and longitude coordinates are correct, the program will compute the free-air gravity anomaly value of the track at the intersection point and display the value on the VT100 screen. The user can then repeat the procedure and enter the coordinates of a different intersection point for the same track.

Program LINPRO

The purpose of the program LINPRO is to set up and solve the linear programming model corresponding to the previously identified tracks and intersection points. To execute this program, the user should type:

```
RUN LINPRO
```

The user will first be asked whether the results of this program are to be printed on the line printer, and will be prompted for a title to be printed at the top of the output. Next, the user will receive the following prompt:

```
IS THE LINEAR PROGRAM ALREADY STORED ON A FILE ?
ENTER Yes OR No
```

For the initial processing of a given set of intersection points, the user should respond with NO. Details for this option will be explained shortly.

Next, the program will prompt the user for the number of tracks and the number of intersection points. The number of tracks must be greater than 1 and less than 26, and the number of intersection points must be greater than 0 and less than 51. For the first intersection point, the user will receive the following prompt:

```
ENTER TRACK NUMBER AND CORRESPONDING VALUE FOR THE
  TWO TRACKS WHICH MEET AT INTERSECTION POINT 1

ENTER A 0 (ZERO) FOR THE TRACK NUMBER TO TERMINATE
  THE PROGRAM
```

The user will then be prompted for the two track number and their corresponding free-air gravity anomaly values at the intersection point. At any intersection point, the two track numbers must be different (i.e., a track cannot intersect itself). The user should also note that the word QUIT is not an acceptable response for this prompting sequence. To terminate the program, the user should enter a zero for either of the track numbers.

After the track numbers and free-air gravity anomaly values have been entered, the program will echo the values and ask the user to make any required changes. An example of a typical display seen on the VT100 screen is:

INTERSECTION	TRACK	VALUE
1	4	-10.2
	5	-17.6

The user now has the option of changing either of the track numbers and/or their corresponding values.

The program will repeat this prompting sequence for each of the intersection points. After initially entering the track numbers and free-air gravity anomaly values, the user will have the option of making any changes and/or corrections. When the user is sure that all the intersection points are correct, the following message will appear on the VT100 screen:

```
SAVE THIS LINEAR PROGRAM ?
ENTER Yes OR No
```

The user now has the option of saving all the information regarding the the intersection points and corresponding track numbers and free-air gravity anomaly values in a data file. This is a very useful feature in that once this data set has been saved, the user can run the linear program model over again, using the same tracks and intersection points, without having to retype all the numbers. If the user decides to save the linear program, there will be a prompt for a file name under which all the data will be stored.

To recall this linear program model, the user should respond with a YES to the previously asked question of whether the linear progam was already stored on the file. There will be a prompt for the file name where the data are stored. After the linear program is read in, the user will have the opportunity to make changes. The altered linear program can be saved in a different file.

The program will then invite the user to place any desired constraints on the individual track adjustments. In this step, the user must rely on judgment and experience in assigning a numerical value to the quality of each track. For example, the adjustment to a high-quality source might be restricted to values below 1 milligal (mgal). On the other hand,

for a poor-quality source, the adjustment might be as much as 20 milligal (mgal). The adjustment for tracks with no constraints can assume arbitrary values.

If the user decides to put constraints on the track adjustments, the following messages will appear on the VT100 screen:

```
THE CONSTRAINTS ARE OF THE FORM : ABS(A(I)) .LE. C

   WHERE A(I) = ADJUSTMENT APPLIED TO TRACK I
            C = POSITIVE REAL NUMBER, OR 0.0

ENTER TRACK NUMBER, I, AND CONSTRAINT VALUE, C

WHEN YOU ARE FINISHED ENTERING CONSTRAINTS
     ENTER -1 FOR THE TRACK NUMBER
```

So, if the user wants the absolute value of the adjustment for track number 3 to be restricted to 5.0 mgal or less, there should be entries of 3 for the track number and 5.0 for the constraint value. The program will echo the track number and the constraint, and ask the user if these are correct. The user can then proceed to enter more track numbers and constraints until a -1 is typed for the track number.

The program will then solve the linear programming problem, and the results will be displayed at the terminal. The results will also be printed on the line printer if the user has previously requested it.

2.8.4 Running the Ocean Track-Crossing Adjustment Programs

This section will present a step-by-step instruction guide on how to combine the four previously described programs to solve the track-crossing adjustment problem.

The first step is for the user to run the program SCATTER on a selected file of ocean data. The user should then use the cursor to select the various tracks. Each track should be written into a separate file. The file names given to the tracks should be similar so that the user can easily identify each track. For example, all the track files could start with the letters TRK, in which case file name TRK4475 will contain the data points for the track with source number 4475. If there are two tracks with the same source number, the user can use trailing letters on the file name (e.g., TRK4475A and TRK4475B).

The user should now run the program CLEANUP on the selected track files to remove any extra data points and to sort the file by latitude and longitude. Following this step, there will be two versions of each of the track files. To remove all the old versions, the user should type PURGE.

Next, the user should create a master file containing all the preprocessed track files. To accomplish this task, the user can use the COPY command. If the user has specified all the track files with unique identifiers, as was suggested earlier, the following command will copy all the track files into a master file.

```
COPY TRK*.DAT MASTER.DAT
```

This command will copy all files whose file names begin with the letters TRK into a file named MASTER.DAT. If the track files were not created in this manner, the user can copy the individual files into a master file with the following command:

```
COPY file1,file2,....,fileN MASTER.DAT
```

Next, the user should again run the program SCATTER using the master data file. This plot will clearly show all the selected tracks and their intersection points. The user should obtain a hard copy of this plot. Note that the user must exit from the program SCATTER before the plot is sent to the line printer.

Now, the user should have available a copy of the ocean track-crossing adjustment worksheet, which is used to record the locations of the intersection points. A sample worksheet is shown in Fig 2.8-1. If the user enters the following command:

PRINT WORKSHEET

a copy of the worksheet will be printed on the line printer.

The user should again run program SCATTER using the master data set. With the cursor, the user determines the latitude and longitude coordinates of the intersection points, and records them on the worksheet. The user should also mark the intersection point number on the hard copy of the scatter plot for later reference.

When all the intersection points have been identified, the user should run the program SPLINE using the individual track files as the input files. It is important to note that these individual track files MUST be preprocessed by the program CLEANUP before they can be used by the SPLINE program. The SPLINE program will determine the free-air gravity anomaly values at the intersection points, using a cubic spline interpolation procedure. Again, the user should use the track-crossing adjustment worksheet to record the free-air gravity anomaly values at the various intersection points.

Intersection Point	Latitude	Longitude	Source Number	Track Number	Value

Figure 2.8-1 Ocean Track-Crossing Adjustment Worksheet

Next, the user must assign track numbers to the selected tracks. Numbering of the tracks should begin with one and proceed sequentially. If each track has a unique source number, then the user can number the tracks consecutively. However, if there are different tracks with the same source number, the user has an option. If the user wants the same adjustment to apply to all tracks with the same source number, then all such tracks should have the same track number. However, if the tracks are to have different adjustments, they should be given different track numbers.

Finally, the user is ready to run the progam LINPRO to find the adjustment factors. The first time the user runs this program, it is necessary to type in the intersection points and the corresponding free-air gravity anomaly values. All of the numbers to be typed in can be read off the worksheet. Once the intersection points and free-air gravity anomaly values have been initially entered, they can be saved in a data file. This file can then be recalled at any time, and the user can make additions and/or corrections as desired.

2.9. ERROR AND DIAGNOSTIC MESSAGES

2.9.1 General Error Messages

The programs which make up the gravity data evaluation software have automatic error traps to flag erroneous data supplied by the user. When the user is prompted to select an option from a menu, the programs check the validity of any selected option, and reprompt the user if an invalid option has been requested. If latitude and longitude values are entered by the user, the programs will check for consistency and reprompt the user if some of the values are suspect.

As was stated in the previous sections, the gravity input file name has no default value. The input file name MUST be specified by the user. If an improper file name is entered, the program will display one of the warning messages listed in Table 2.9-1 on the VT100 screen.

TABLE 2.9-1

WARNING MESSAGES

MESSAGE	POSSIBLE CAUSES
COULD NOT FIND FILE: filename CHECK SPELLING	The program could not find the input file specified by the user. Make sure the file name is spelled correctly and all necessary qualifiers are included in the file name.
ERROR IN OPENING FILE: filename	The program could not open the input file for reading. Could happen if another user is also reading same file. Wait until file is released, or use a different file.
FILE SPECIFICATION ERROR	User has entered an invalid file name. Possible causes of invalid file names are too many characters (maximum of 9) or illegal characters in file name.

All three of these messages are caused by nonfatal errors which are trapped by the program. In each case, the user is reprompted to enter a new input file name.

There is one fatal error which will cause each of the programs to terminate execution. If an error occurs while the program is reading the input gravity file, the following message will appear on the screen:

```
AN ERROR OCCURRED WHILE READING FILE : filename
CHECK FILE FOR PROPER INPUT FILE FORMAT
```

The user should examine the input file to make sure that the records in the file are in the WSS online format (see Section 2.2).

Some of the programs also have errors specifically related to the individual program. These are the scatter plot program, the statistical plot program, and the ocean track-crossing adjustment programs. A description of these errors will now be presented.

2.9.2 Scatter Plot Program Error Messages

The scat'er plot program contains a fatal error message that involves the system plot routine SUPMAP. This routine is called to draw political boundaries and coastlines which may lie within the limits of the scatter plot. If an error occurs in this routine, the following message will appear on the VT100 screen:

```
ERROR IN SYSTEM PLOT ROUTINE SUPMAP
CHECK PLOT REFERENCE MANUAL  P. 147
FOR ERROR NUMBER IER
```

where IER = error number

The plot reference manual (Ref. 7) has a list of the various error flags and their explanation. The most common error is caused by improper latitude-longitude limits of the plot.

2.9.3 Statistical Plot Program Error Messages

In addition to the errors mentioned above, there are other nonfatal errors in the robust estimation. If there are not enough points to do the robust estimation computations, the following message will appear on the VT100 screen:

*** ERROR: NOT ENOUGH POINTS IN BIWEIGHT

Many of the robust estimators cannot function properly with small amounts of data. The user should provide more data for the estimators.

Another error in the robust estimators may occur in the M-estimate and sine-estimate if the algorithm does not converge after 25 iterations. The message presented will be of this type:

***** WARNING: SINE-ESTIMATE DOES NOT CONVERGE AFTER 25 ITERATIONS

This will occur if there is a small number of widely scattered data points.

2.9.4 Ocean Track-Crossing Adjustment Programs Error Messages

For the program CLEANUP, the following message is due to a fatal error in the sort routines:

FATAL ERROR IN SORTING ROUTINES

Since the error occurred in the system sorting routines, there could be a problem with the system software. The user should consult the systems manager if this error arises.

The following error message may appear on the VT100 screen while executing the program SPLINE:

```
AN ERROR OCCURRED IN THE IMSL ROUTINE WHICH PERFORMS
   THE SPLINE FIT.  LOOK IN THE IMSL DOCUMENTATION
   UNDER THE ROUTINE NAMED :  ICSSCV
   FOR ERROR NUMBER IER
```

where IER = error number

This error is probably caused by duplicate points in the track file. The user should run the program CLEANUP on the track file, and then try the program SPLINE again.

When the user is running the program LINPRO, the following error message may appear on the VT100 screen:

```
AN ERROR OCCURRED IN THE IMSL ROUTINE WHICH SOLVES
   THE LINEAR PROGRAM.  LOOK IN THE IMSL DOCUMENTATION
   UNDER THE ROUTINE NAMED : ZX3LP
   FOR ERROR NUMBER  IER
```

where IER = error number

This error could occur if the user specifies too many tracks and/or intersection points. If the linear program problem is very large, it should be separated into smaller sections.

3. DETAILED PROGRAM DESCRIPTION

3.1 INTRODUCTION

The purpose of this section is to provide detailed documentation for the programs which make up the gravity data evaluation software. Section 3.2 will describe the common blocks used by many of the programs. The next sections will describe the various main programs of the gravity data evaluation software. Each section also contains a list of all the subroutines used by the programs. Section 3.8 fully documents the upper-level subroutines, and Section 3.9 describes some of the mathematical algorithms used by the various routines.

3.2 DESCRIPTION OF COMMON BLOCKS

This section describes the two major common blocks used by many of the gravity data evaluation programs. A list of names and descriptions of the variables in each common block is also included.

3.2.1 Common Block GRAVITY

The purpose of the common block GRAVITY, which is defined in the included file GRAVITY.FOR, is to store all the data fields which are part of the input gravity file. This common block is used in the subroutines PRINT and SAVE. The variables comprising the common block GRAVITY are:

NAME	TYPE	DIMENSIONS	DESCRIPTION
SOURCE	INTEGER*4	(5000)	Source Number
LAT	REAL*4	(5000)	Latitude (Decimal Degrees)
LON	REAL*4	(5000)	Longitude (Decimal Degrees)
ELEV	REAL*4	(5000)	Elevation (Meters)
OG	REAL*4	(5000)	Observed Gravity (Less 976,000 mgal)
FA	REAL*4	(5000)	Free-Air Gravity Anomaly (mgal)
BA	REAL*4	(5000)	Bouguer Gravity Anomaly (mgal)

3.2.2 Common Block LEX

The purpose of the common block LEX is to signal the main program which option the user has selected from the plot option menu. The common block is used in the subroutine LXPRMT, and it contains only one variable:

NAME	TYPE	DIMENSIONS	DESCRIPTION
ISIGN	INTEGER*4	-	Plot Option Flag

The contour plot program and the surface plot program also use common blocks to interface with the system plotting routines. Descriptions of these common blocks are given in The Analytic Sciences Corporation (TASC) Graphics Software Package Reference Manual (Ref. 3).

3.3 THE SCATTER PLOT PROGRAM (SCATTER)

3.3.1 Program Organization

The scatter plot program is part of the gravity data evaluation software. The program is designed as a stand-alone main program, with calls to several upper-level subroutines to facilitate many of the user options. The program uses as input any gravity file which is in the WSS online format, which is described in Section 2.2. Outputs from the program include hard copy scatter plots and subfiles of selected data points.

Figure 3.3-1 shows a logic flowchart of the scatter plot program. The major processing sections are shown as blocks in the figure. The various user options are each controlled by a call to an upper-level subroutine. A detailed description of the main program is presented in the next section. A list of the names and functions of all the subroutines used by the scatter plot program is given in Section 3.3.3.

3.3.2 Main Program Description

The purpose of the main program is to construct the scatter plot and to respond to the options which the user requests. The program is divided into three major sections. They are:

- Read the input gravity data file
- Construct the scatter plot
- Prompt the user for various options.

The first step of the program is to read the input gravity data file and establish the latitude and longitude

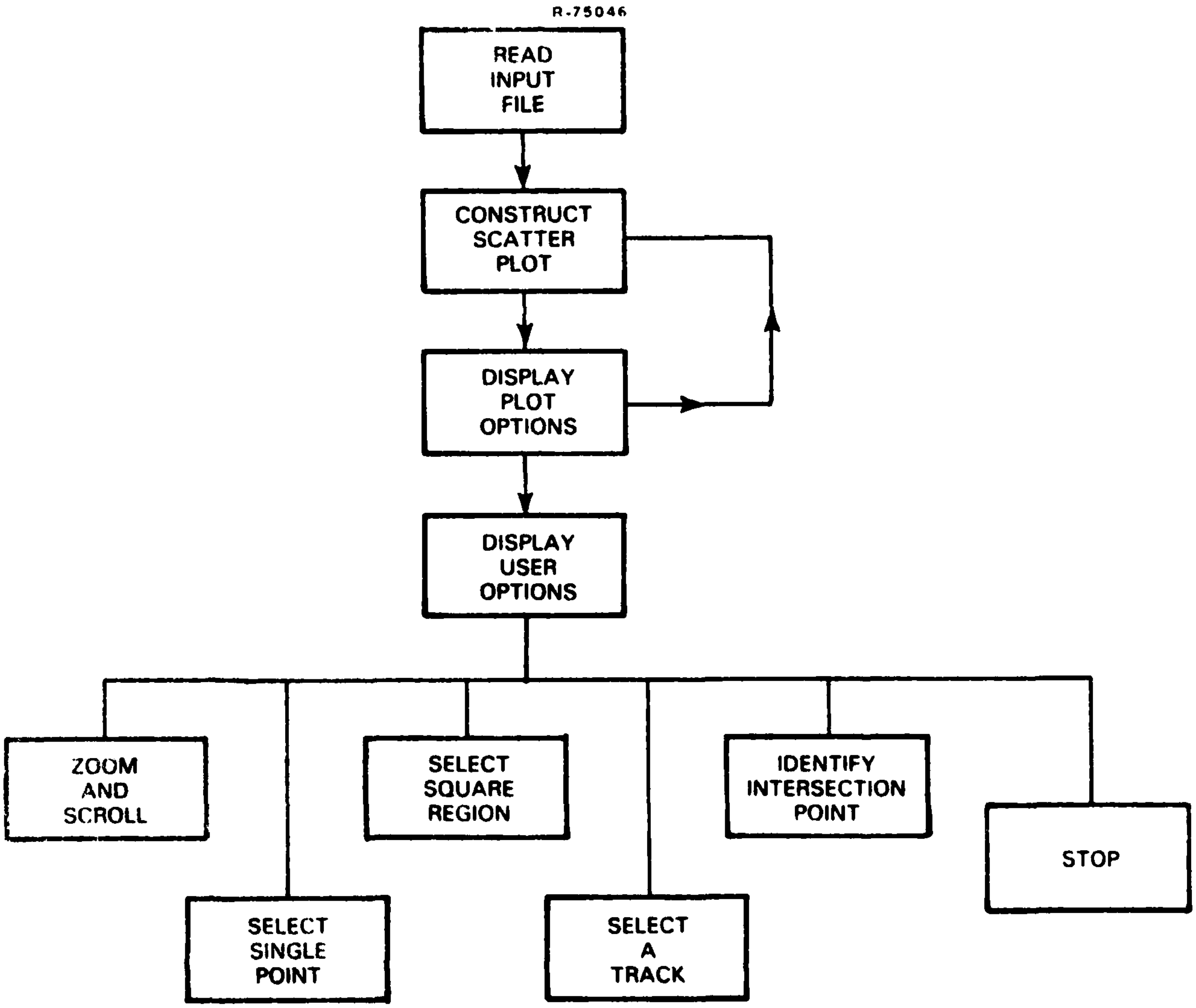

Figure 3.3-1 Logic Flowchart for Program SCATTER

limits for the scatter plot. The program determines the minimum and maximum values for both latitude and longitude from the points in the gravity data file. The default scatter plot limits are determined by rounding the minimum and maximum latitude and longitude either up or down to the nearest 0.25 degree. The user can keep the default value, or specify new latitude-longitude limits.

The second step of the program is to construct the scatter plot. The scatter plot is constructed by calls to SUPMAP, SUPCON, and PWRY, which are all high level routines in the system plot library (Ref. 3). The subroutine SUPMAP sets up the boundaries of the scatter plot, and draws any political boundaries and coastlines which may lie within the limits of the plot. The subroutine SUPCON is then called to convert latitude-longitude coordinates to Mercator map projection co-ordinates, and PWRY draws alphanumeric characters for labeling plots.

When the scatter plot is completed, the plotting option menu is displayed on the VT100 screen. The routine which displays the menu is LXPRMT. The user has the option of obtaining a hard copy of the scatter plot, creating a new scatter plot, continuing in the program, or terminating the program. The hard copy option is controlled by routines in the system plot library. If a new scatter plot is selected, control of the program returns to the plotting limits prompts.

Continuing in the program, the user is next presented with a menu for selecting various options, such as zooming, scrolling, and point selection using the cursor. When an option is selected, control of the program passes to an upper-level subroutine, where most of the numerical processing is carried out. A complete description of each of the upper-level subroutines is presented in Section 3.8. Upon completion of one of the options, the program returns to the menu selection, where the user can then select a different option, or select the same one again. The program stops execution when the user selects the terminate option.

3.3.3 Subroutine Names and Functions

UPPER-LEVEL SUBROUTINES

ZOOM	Control zoom and scroll options
FINDPT	Select point in gravity file closest to the cursor
FINDSQ	Select points in gravity file within a rectangular region
FINDTRK	Select points in gravity file which lie along a track
FINDINTER	Determine latitude and longitude coordinates of a track intersection point

SYSTEM PLOTTING ROUTINES

SUPMAP	Draw coastlines within boundaries of scatter plot
SUPCON	Convert latitude-longitude coordinates to map plotting coordinates
PWRY	Plot a character at a specified point
LXLEV	Change the plot color level
GETSET	Return size of the current plot
CURS	Set up and load cross hair cursor pattern
FRAME	Close the plotting utilities
LXPRMT	Prompt user for plotting options

LEXIDATA LIBRARY ROUTINES

DSCLR	Clear the graphics terminal screen
DSCER	Erase matrix cursor
DSCXY	Set the cursor position

DSGXY	Get the cursor position
DSZOM	Invoke zoom option
WAIT	Stop processing for a period of time

PLOTTING LIMITS ROUTINES

CORNER	Round given latitude and longitude values to nearest 0.25 degree
NEWVALS	Prompt user for new latitude and longitude limits for plotting

CURSOR CONTROL ROUTINES

CURSOR	Display white cursor on the graphics terminal
READCURS	Read current cursor position and switch settings
RSET	Reset scrolled origin and zoom level

COORDINATE TRANSFORMATION ROUTINES

CONZOOM	Convert the zoomed cursor coordinates to the original plotter coordinates
CONUSER	Convert plotter coordinates to user coordinates

OUTPUT ROUTINES

PRINT	Print records in gravity file corresponding to the selected points
SAVE	Save selected points in a specified file
OFILE	Open and close appropriate files

SYSTEM UTILITY ROUTINES

INPCHR	Prompt for input of character string

INPIN4	Prompt for input of integer variable
VTSCROLL	Set up scrolling window for the VT100 terminal

SCATTER PLOT UTILITY ROUTINES

SQUARE	Draw rectangular region on scatter plot
LABELS	Put latitude and longitude limits on the scatter plot
HOLD	Read trackball switches until all are in the OFF position
HALT	Stop program execution
YESNO	Check for a YES or NO answer

3.4 THE CONTOUR PLOT PROGRAM (CONPLOT)

3.4.1 Program Organization

The contour plot program is part of the gravity data evaluation software. The program is designed as a stand-alone main program, with calls to several upper-level subroutines to facilitate many of the user options. The program uses as input any gravity file which is in the WSS online format, which is described in Section 2.2. Outputs from the program include hard copy contour plots and subfiles of selected data points.

A logic flowchart of the contour plot program is shown in Fig. 3.4-1. The major processing sections are shown as blocks in the figure. The various user options are each controlled by an upper-level subroutine call. A detailed description of the main program is presented in the next section. A list of the names and functions of all the subroutines used by the contour plotting program is given in Section 3.4.3.

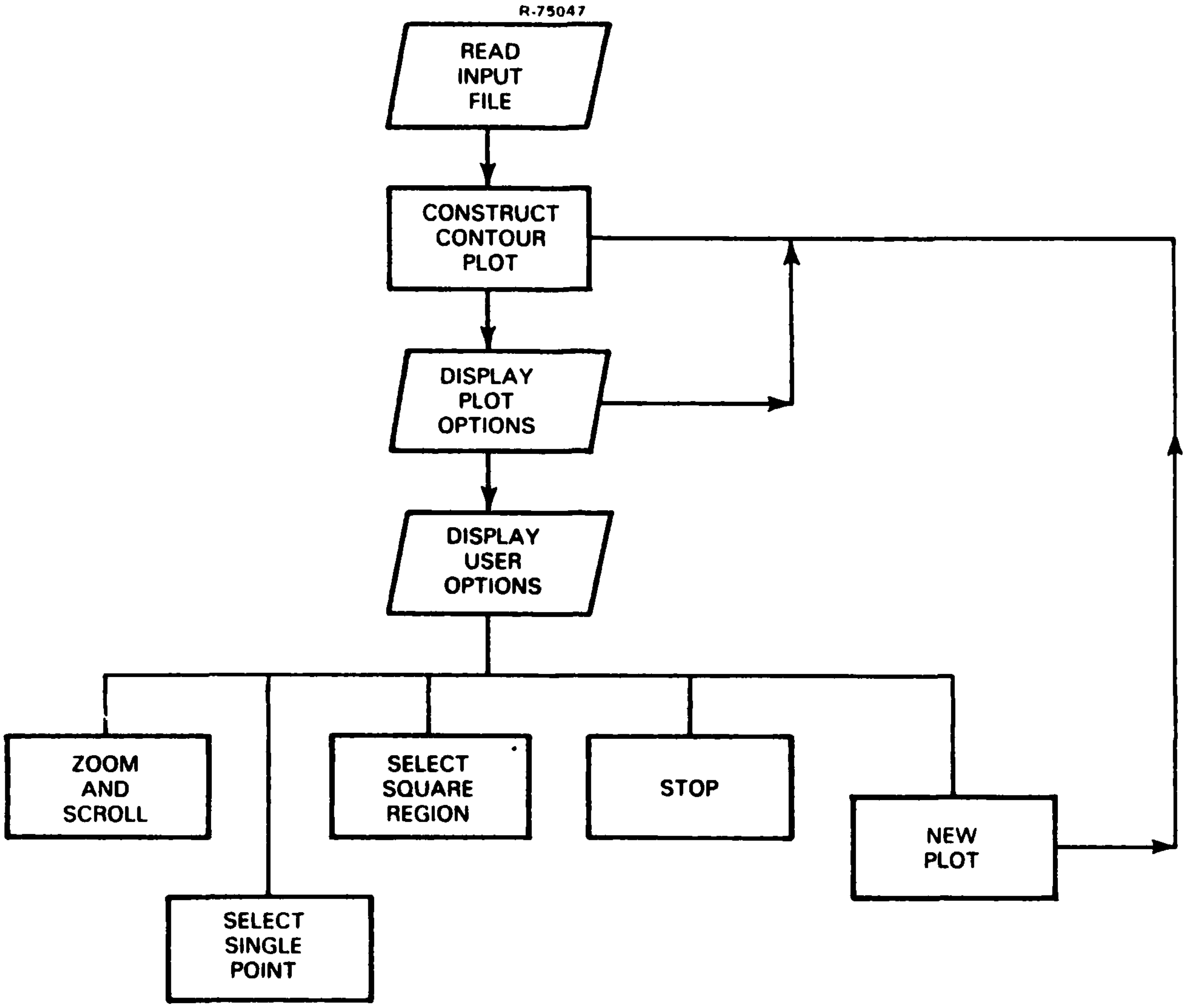

Figure 3.4-1 Logic Flowchart for Program CONPLOT

3.4.2 Main Program Description

The purpose of the main program is to construct the contour plot and to respond to the options which the user requests. The program is divided into four major sections. They are:

- Read the input gravity data file
- Grid the unevenly spaced data
- Construct the contour plot
- Prompt the user for various options.

The first step of the program is to read the input gravity data file and establish the latitude and longitude limits for the contour plot. The program determines the minimum and maximum values for both latitude and longitude from the points in the gravity data file. The default contour plot limits are determined by rounding the minimum and maximum latitude and longitude either up or down to the nearest 0.25 degree. The user can keep the default values, or specify new latitude-longitude limits.

The next step of the program is to grid the data and construct the contour plot. The gridding algorithm used in the program is based on a weighted averaging technique. Details of the gridding algorithm are presented in Section 3.8. The contour plot is produced by calling subroutine CONREC. The scatter plot, which is overlayed with the contour plot, is produced by calls to subroutine PWRY. Both of these subroutines are high level routines in the system plot library (Ref. 3).

When the contour plot is completed, the plotting option menu is displayed on the VT100 screen. The routine which displays the menu is LXPRMT. The user has the option of obtaining a hard copy of the contour plot, creating a new contour plot, continuing in the program, or terminating the program. The hard copy option is controlled by routines in the system plot library. If a new contour plot is selected, control of the program returns to the plotting limits prompts.

Continuing with the program, the user is next presented with a menu for selecting various options, such as zooming, scrolling, and point selection using the cursor. When an option is selected, control of the program passes to an upper-level subroutine, where most of the numerical processing is carried out. Upon completion of one of the options, the program returns to the menu selection, where the user can then select a different option, or select the same one again. The program stops execution when the user selects the terminate option.

3.4.3 Subroutines Names and Functions

UPPER-LEVEL SUBROUTINES

AVER	Determine value at a grid point
ZOOM	Control zoom and scroll option
FINDPT	Select point in gravity file closest to the cursor
FINDSQ	Select points in gravity file within a rectangular region

SYSTEM PLOTTING ROUTINES

CONREC	Draw a contour map from data stored in a rectangular array
PWRY	Plot a character at a specified point
LXLEV	Change the plot color level
GETSET	Return size of the current plot
CURS	Set up and load cross hair cursor pattern
FRAME	Close the plotting utilities
LXPRMT	Prompt user for plotting options

LEXIDATA LIBRARY ROUTINES

DSCLR	Clear the graphics terminal screen
DSCER	Erase matrix cursor
DSCXY	Set the cursor position
DSGXY	Get the cursor position
DSZOM	Invoke zoom option
WAIT	Stop processing for a period of time

PLOTTING LIMITS ROUTINES

CORNER	Round given latitude and longitude values to nearest 0.25 degree
NEWVALS	Prompt user for new latitude and longitude limits for plotting

CURSOR CONTROL ROUTINES

CURSOR	Display white cursor on the graphics terminal
READCURS	Read current cursor position and switch settings
RSET	Reset scrolled origin and zoom level

COORDINATE TRANSFORMATION ROUTINES

CONZOOM	Convert the zoomed cursor coordinates to the original plotter coordinates
CONUSER	Convert plotter coordinates to user coordinates

OUTPUT ROUTINES

PRINT	Print records in gravity file corresponding to the selected points

SAVE	Save selected points in a specified file
OFILE	Open and close appropriate files

SYSTEM UTILITY ROUTINES

INPCHR	Prompt for input of character string
INPIN4	Prompt for input of integer variable
VTSCROLL	Set up scrolling window for the VT100 terminal

CONTOUR PLOT UTILITY ROUTINES

SQUARE	Draw rectangular region on contour plot
PLUCK	Select data points near a grid point
HOLD	Read trackball switches until all are in the OFF position
HALT	Stop program execution
YESNO	Check for a YES or NO answer

3.5 THE THREE-DIMENSIONAL SURFACE PLOT PROGRAM (SURPLOT)

3.5.1 Program Organization

The surface plot program is part of the gravity data evaluation software. The program is designed as a stand-alone main program, with calls to upper-level subroutines to execute many of the user options. The program uses as input any gravity file in the WSS online format, which is described in Section 2.2. Outputs from the program include hard copy surface plots.

Figure 3.5-1 shows a logic flowchart of the surface plot program. The major processing sections are shown as blocks in the figure. Most of the various user options are controlled by an upper-level subroutine call. A detailed description of the main program is presented in the next section. A list of the names and functions of all the subroutines used by the surface plotting program is given in Section 3.5.3.

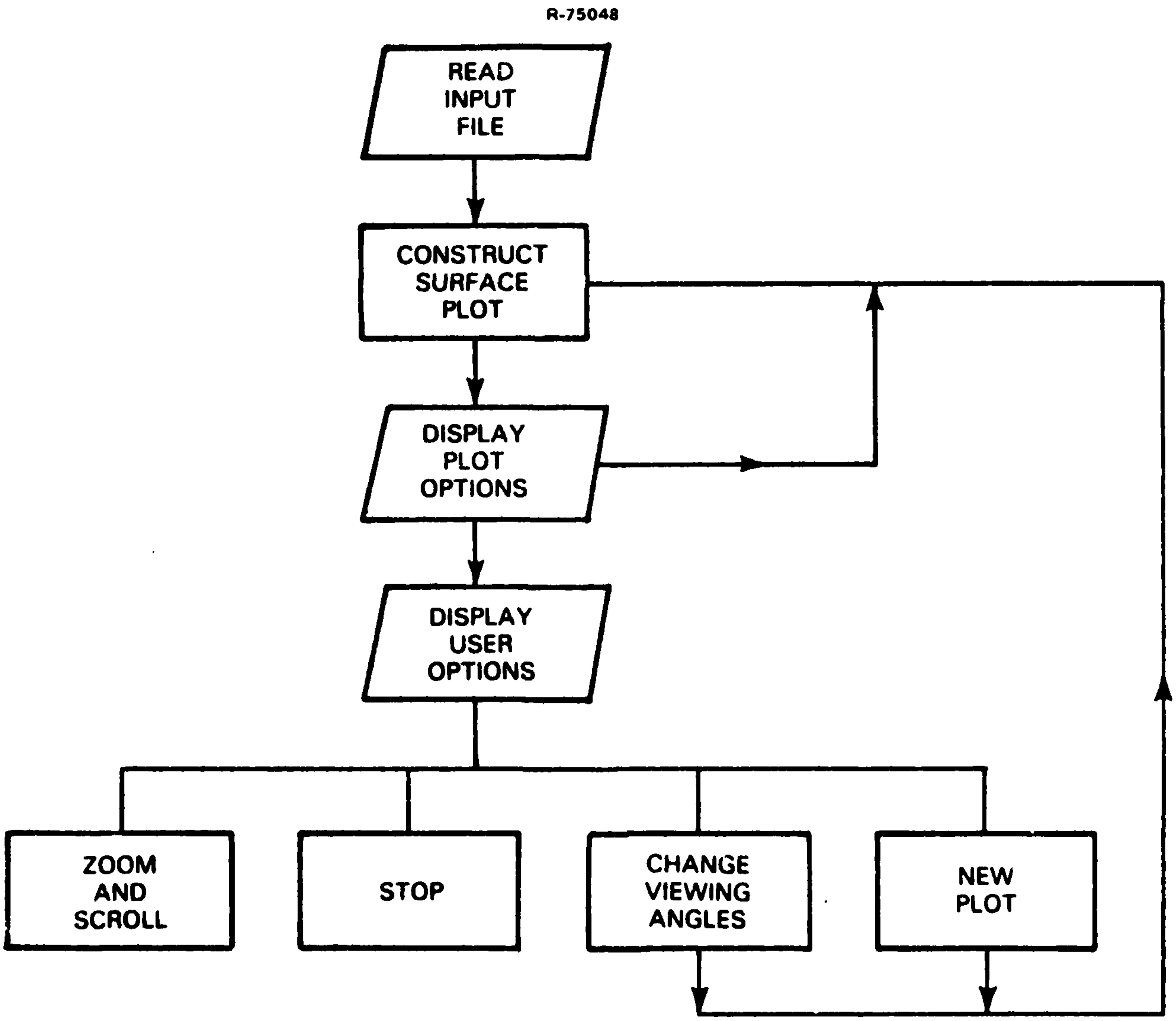

Figure 3.5-1 Logic Flowchart for Program SURPLOT

3.5.2 Main Program Description

The purpose of the main program is to construct the surface plot and to respond to the options which the user requests. The program is divided into four major sections. They are:

- Read the input gravity data file
- Grid the unevenly spaced data
- Construct the surface plot
- Prompt the user for various options.

The first step of the program is to read the input gravity data file and establish the latitude and longitude limits for the surface plot. The program determines the minimum and maximum values for both latitude and longitude from the points in the gravity data file. The default surface plot limits are determined by rounding the minimum and maximum latitude and longitude either up or down to the nearest 0.25 degree. The user can keep the default value, or specify new latitude-longitude limits.

The next step of the program is to grid the data and construct the surface plot. The gridding algorithm used in the program is based on a weighted averaging technique. Details of the gridding algorithm are presented in Section 3.8. Next, the user is prompted for two line-of-sight viewing angles, which determine how the surface plot is displayed on the graphics terminal. The surface plot is then drawn by a call to EZSRFC, which is a high-level routine in the system plot library (Ref. 3).

When the surface plot is completed, the plotting option menu is displayed on the VT100 screen. The routine which displays the menu is LXPRMT. The user has the option of obtaining

a hard copy of the surface plot, creating a new surface plot, continuing in the program, or terminating the program. The hard copy option is controlled by routines in the system plot library. If a new surface plot is selected, control of the program returns to the plotting limits prompts.

Continuing with the program, the user is next presented with a menu for selecting various options, such as zooming, scrolling, and changing the plot viewing angle. If the zoom and scroll option is selected, control of the program passes to an upper-level subroutine. A complete description of the upper-level subroutines is presented in Section 3.8. If the user selects the change viewing angle option, the program control returns to the viewing angle prompt. The surface plot is redrawn, and the plot menu option is again displayed on the screen. The program stops execution when the user selects the terminate options.

3.5.3 Subroutine Names and Functions

UPPER-LEVEL SUBROUTINES

AVER	Determine value at a grid point
ZOOM	Control zoom and scroll option

SYSTEM PLOTTING ROUTINES

EZSRFC	Draw a three-dimensional surface plot from a rectangular array
PWRY	Plot a character string
FRAME	Close the plotting utilities
LXPRMT	Prompt user for plotting options

LEXIDATA LIBRARY ROUTINES

DSCLR	Clear graphics terminal screen
DSZOM	Invoke zoom option
WAIT	Stop processing for a period of time

PLOTTING LIMITS ROUTINES

CORNER	Round given latitude and longitude values to nearest 0.25 degree
NEWVALS	Prompt user for new latitude and longitude limits for plotting

SYSTEM UTILITY ROUTINES

INPCHR	Prompt for input of character string
INPRL4	Prompt for input of real variable

SURFACE PLOT UTILITY ROUTINES

PLUCK	Select data points near a grid point
RSET	Reset scroll origin and zoom level
HOLD	Read trackball switches until all are in the OFF position
HALT	Stop program execution
YESNO	Check for a YES or NO answer

3.6 THE ROBUST ESTIMATION AND STATISTICAL PLOT PROGRAM (STATPLOT)

3.6.1 Program Organization

The statistical plot program is part of the gravity data evaluation software. The program is designed as a stand-alone main program, with calls to several upper-level subroutines

to facilitate many of the user options. The program uses as input any gravity file in the WSS online format, which is described in Section 2.2. Outputs from the program include hard copy plots and files of selected data points.

A logic flowchart of the statistical plot program is shown in Fig. 3.6-1. The major processing sections are shown as blocks in the figure. The various user options are each controlled by an upper-level subroutine call. A detailed description of the main program is presented in the next section. A list of the names and functions of all the subroutines used by the statistical plotting program is given in Section 3.6.3.

3.6.2 Main Program Description

The purpose of the main program is to construct the statistical plot and respond to user selected options. The program is divided into three major sections. They are:

- Read the input gravity data file
- Construct the appropriate plot
- Prompt the user for various options.

The first step of the program is to read the input gravity data file specified by the user. The latitude and longitude ranges of the points in the file are displayed on the VT100 terminal, along with the number of data points in the file.

The program then calls the appropriate routines to draw the user-selected plot (i.e., either a QQ plot or an ECDF plot). Both types of plot are constructed by calling several

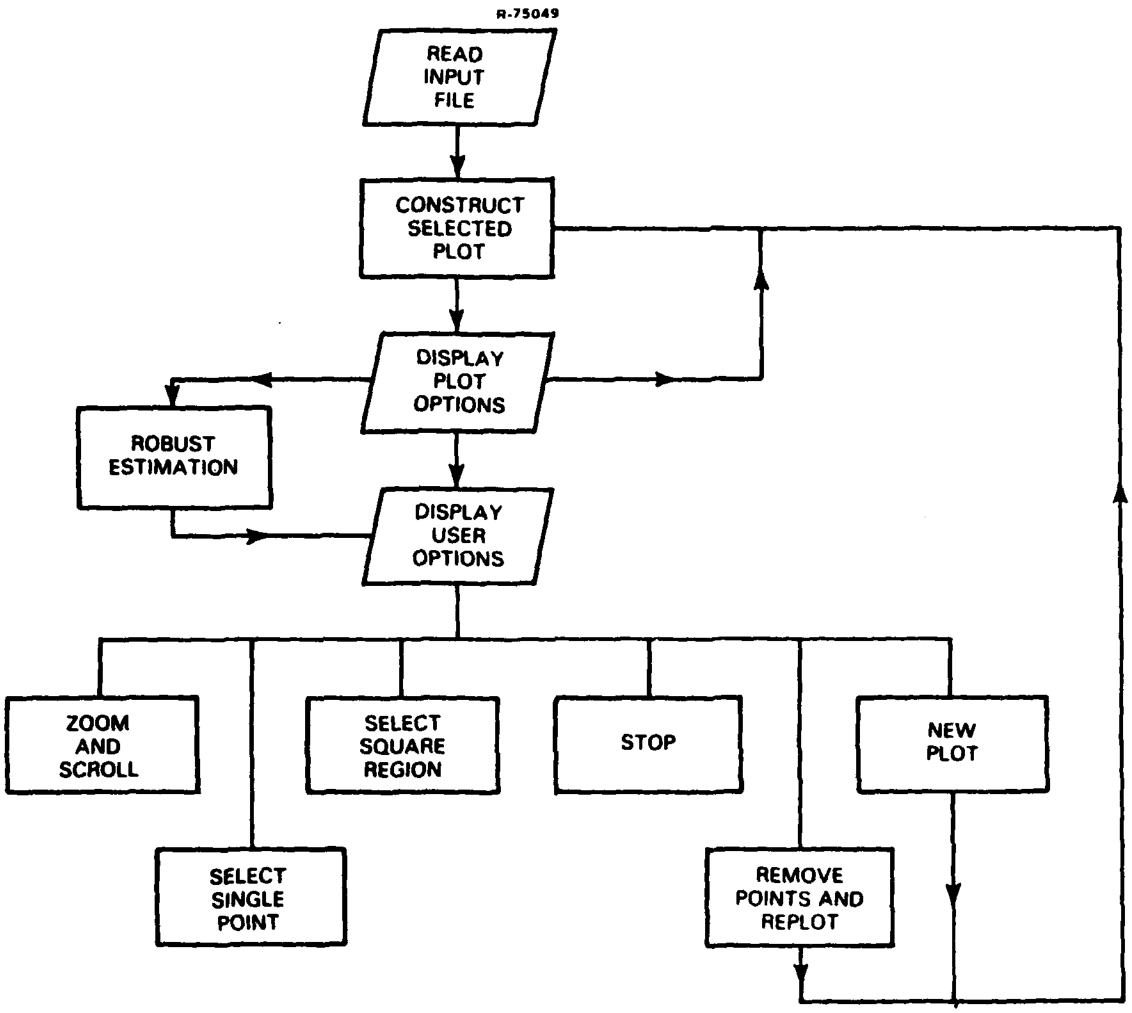

Figure 3.6-1 Logic Flowchart for Program STATPLOT

subroutines in the system plot library (Ref. 3). After the plot has been drawn, the user has the option to apply the robust estimators to the plotted data set. The estimators are called by the subroutine ROBUST. A description of this routine is given in Section 3.8.

After the robust estimation section, the user is presented with a menu to select various options such as replotting, zooming, scrolling, and point selection using the cursor.

When the zooming, scrolling, or point selection options are selected, control of the program passes to an upper-level subroutine, where most of the numerical processing is carried out. Upon completion of one of these options, the program returns to the menu selection, where the user can then select a different option, or select the same one again. When the user selects the replot option, control of the program returns to the plot generation routines. For a new plot, control returns to the plot selection prompt. The program stops execution when the user selects the terminate option.

3.6.3 Subroutine Names and Functions

UPPER-LEVEL SUBROUTINES

QQPLOT	Construct a QQ plot
ECDFPLOT	Construct an ECDF plot
ROEUST	Controller for the robust estimation routines
ZOOM	Control zoom and scroll option
FINDPT	Select point in gravity file closest to the cursor
FINDSQ	Select points in gravity file within a rectangular region

ROBUST ESTIMATOR ROUTINES

ADAPTRIM	Compute an adaptive trimmed mean
BHEST	Compute the Bickel-Hodges estimate
BIWEIGHT	Compute the biweight estimate
FLATLABS	Compute the least absolute average with flattened weights
HLEST	Compute the Hodges-Lehmann estimate

MEAN	Compute the mean
MEDIAN	Find the median
MEST	Compute M-estimates of type 1 or 2
QUARTILE	Find the upper and lower quartiles
SINEST	Compute the sine-estimate
STDEV	Compute the standard deviation
TRIMMED	Compute the trimmed mean

ROBUST ESTIMATOR UTILITY ROUTINES

COMPARE	Compare one character string with another for equality
PRTHELP	Print a list of available robust estimator commands

SYSTEM PLOTTING ROUTINES

AGSETF	Set a plotting parameter
ANOTAT	Provide plot labels
DISPLA	Control plot parameter
EZXY	Draw an X-Y plot
FLUSH	Force output of the plot buffer
FRAME	Close the plotting utilities
GETSET	Return size of the current plot
CURS	Set and load cross hair cursor pattern
LXLEV	Change the plot color level
LXPRMT	Prompt user for plotting options
PWRY	Plot a character at a specified point

LEXIDATA LIBRARY ROUTINES

DSCLR	Clear the graphics terminal screen
DSCER	Erase matrix cursor
DSCXY	Set the cursor position
DSCSL	Load cursor
DSGXY	Get the cursor position
DSLWT	Load color look-up table
DSVEC	Draw a vector
DSZOM	Invoke zoom option
WAIT	Stop processing for a period of time

CURSOR CONTROL ROUTINES

CURSOR	Display white cursor on the graphics terminal
READCURS	Read current cursor position and switch settings
RSET	Reset scrolled origin and zoom level

COORDINATE TRANSFORMATION ROUTINES

CONZOOM	Convert the zoomed cursor coordinates to the original plotter coordinates
CONUSER	Convert plotter coordinates to user coordinates

OUTPUT ROUTINES

PRINT	Print records in gravity file corresponding to the selected points
SAVE	Save selected points in a specified file
OFILE	Open and close appropriate files

SYSTEM UTILITY ROUTINES

INPCHR	Prompt for input of character string
INPIN4	Prompt for input of integer variable
INPRL4	Prompt for input of real variable
VTSCROLL	Set up scrolling window for the VT100 terminal

STATISTICAL PLOT UTILITY ROUTINES

SQUARE	Draw a rectangular region on the plot
HOLD	Read trackball switches until all are in the OFF position
HALT	Stop program execution
YESNO	Check for a YES or NO answer

3.7 OCEAN TRACK-CROSSING ADJUSTMENT PROGRAMS

3.7.1 Program SCATTER

The scatter plot program is fully documented in Section 3.3 of this manual. The user should consult this section for a detailed description of the scatter plot program.

3.7.2 Program CLEANUP

Main Program Description - The purpose of the program CLEANUP is to prepare the ocean track files for use by the program SPLINE. The program has two major functions. They are:

- To remove extraneous points belonging to other sources from the track file
- To sort the track file by latitude and longitude.

Figure 3.7-1 illustrates the logic flow of the program CLEANUP. The program first opens the ocean track data file and prompts the user for a source number. The program then reads the track file one record at a time. If the source number of the record matches the source number entered by the user, the record is written to a temporary file called ZZYYXX1.TMP.

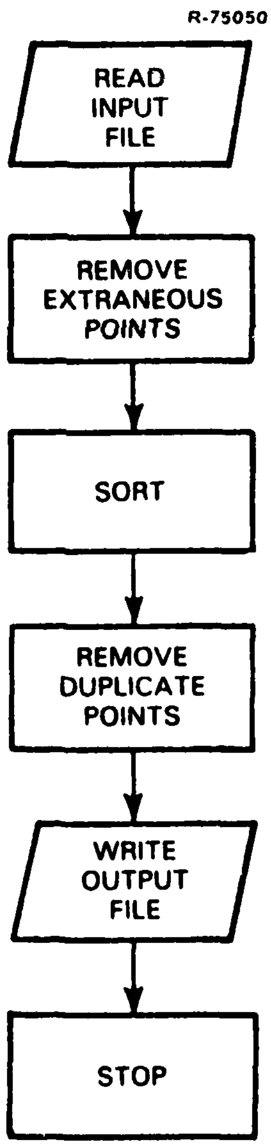

Figure 3.7-1 Logic Flowchart for Program CLEANUP

The next section of the program sorts the temporary file ZZYYXX1.TMP by latitude and longitude. The program uses the sort routines included as part of the VAX/VMS Common Run-Time Library. Output from the sort routines consists of another temporary file, called ZZYYXX2.TMP, which contains the sorted records.

The program then reads the sorted temporary file, ZZYYXX2.TMP, and scans the file for duplicate records. Duplicate records are two adjacent records in the sorted file which have the same latitude and longitude. If duplicate records are detected, a flag is set on the second record.

Finally, the program opens a new file with the same name as the track input file name. All the sorted records are written to the file, except for those records flagged as duplicates. The two temporary files are deleted from the disk.

List of Subroutines - The following routines are all part of the VAX/VMS Common Run-Time Library. Detailed description of these routines can be found in volume 3A of the VAX/VMS Reference Manuals.

SOR$PASS_FILES	Pass input and output file specifications
SOR$INIT_SORT	Pass parameters that specify sort options
SOR$SORT_MERGE	Sort the file
SOR$END_SORT	Close files and release memory

3.7.3 Program SPLINE

Main Program Description - The purpose of the program SPLINE is to compute the free-air gravity anomaly value along

a track at an intersection point. Since actual gravity measurements will ordinarily not have been made at the exact intersection point, the free-air gravity anomaly value at the intersection point must be determined by interpolation. Using least-squares techniques, a cubic spline is fitted to the data along the track near the intersection point. The value at the intersection point can then be calculated by evaluating the cubic spline there.

A logic flowchart of the program SPLINE is shown in Fig. 3.7-2. The program first reads the ocean track file which has been processed by the CLEANUP procedure. For each individual point along the track, the distance from that point to the first point in the file is calculated using the following equation:

$$D = R_e \cos^{-1}[\sin\phi_1 \sin\phi_i + \cos\phi_1 \cos\phi_i \cos\Delta\lambda] \qquad (3.7\text{-}1)$$

where

R_e = radius of earth 6378.135 km

(ϕ_1, λ_1) = latitude-longitude coordinates of the first data point

(ϕ_i, λ_i) = latitude-longitude coordinates of the i^{th} data point

$\Delta\lambda = \lambda_1 - \lambda_i$

Next, the user specifies the latitude and longitude coordinates of the intersection point. The distance from the intersection point to the first point along the track is calculated using Eq. 3.7-1. Using the previously computed distances, the program then finds the nearest 10 points along the track on each side of the intersection point. If the intersection point is near the beginning or end of the track and 10 points cannot be selected on one side, then the program will select fewer than 10 points.

R-75051

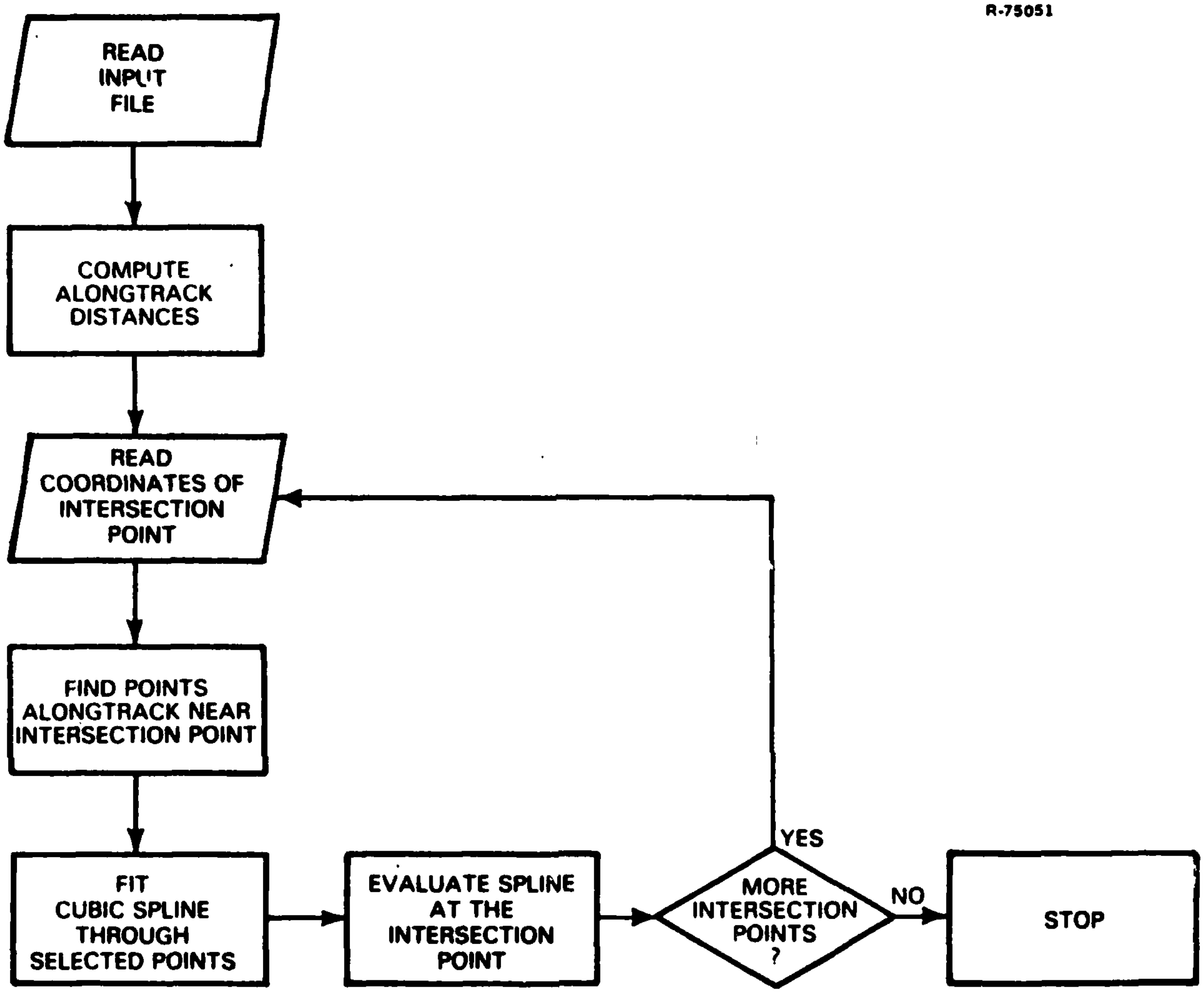

Figure 3.7-2 Logic Flowchart for Program SPLINE

A cubic spline is now fitted through the selected points. The independent variable is the distance from the selected points to the intersection point, where data points which are below the intersection point are assigned negative values. (For a horizontal track, points to the left have negative values.) The dependent variable is the free-air gravity anomaly values of the selected points. The spline is fitted to the selected points using the IMSL routine ICSSCV. Using the coefficients returned by the IMSL routine, the value of the spline is then computed at the intersection point.

The program then asks the user whether there are more intersection points for this track. If so, the user is prompted for new latitude and longitude coordinates. If there are no more intersection points, the program terminates execution.

LIST OF SUBROUTINES

VSRTRD	IMSL sort routine
ICSSCV	IMSL cubic spline routine
INPCHR	System utility routine used to prompt for character string input
VTSCROLL	System utility routine used to set up scrolling window for the VT100 terminal
YESNO	Check for a YES or NO answer
HALT	Stop program execution

3.7.4 Program LINPRO

Main Program Description - The purpose of the program LINPRO is to construct and solve the linear programming model corresponding to the selected tracks and intersection points. The model also includes the constraints which the evaluator may place on the individual track adjustment terms. The solution to the linear programming model is a set of track adjustments which will minimize the maximum absolute discrepancy at the intersection points, subject to the constraints on the individual track adjustments. Figure 3.7-3 illustrates the logic flow of the program LINPRO.

First, the program asks the user whether the linear program model is already stored on the disk. If so, then the linear program model is read from the disk data file. If not, the program prompts the user for the number of tracks and the number of intersection points. Then, for each intersection

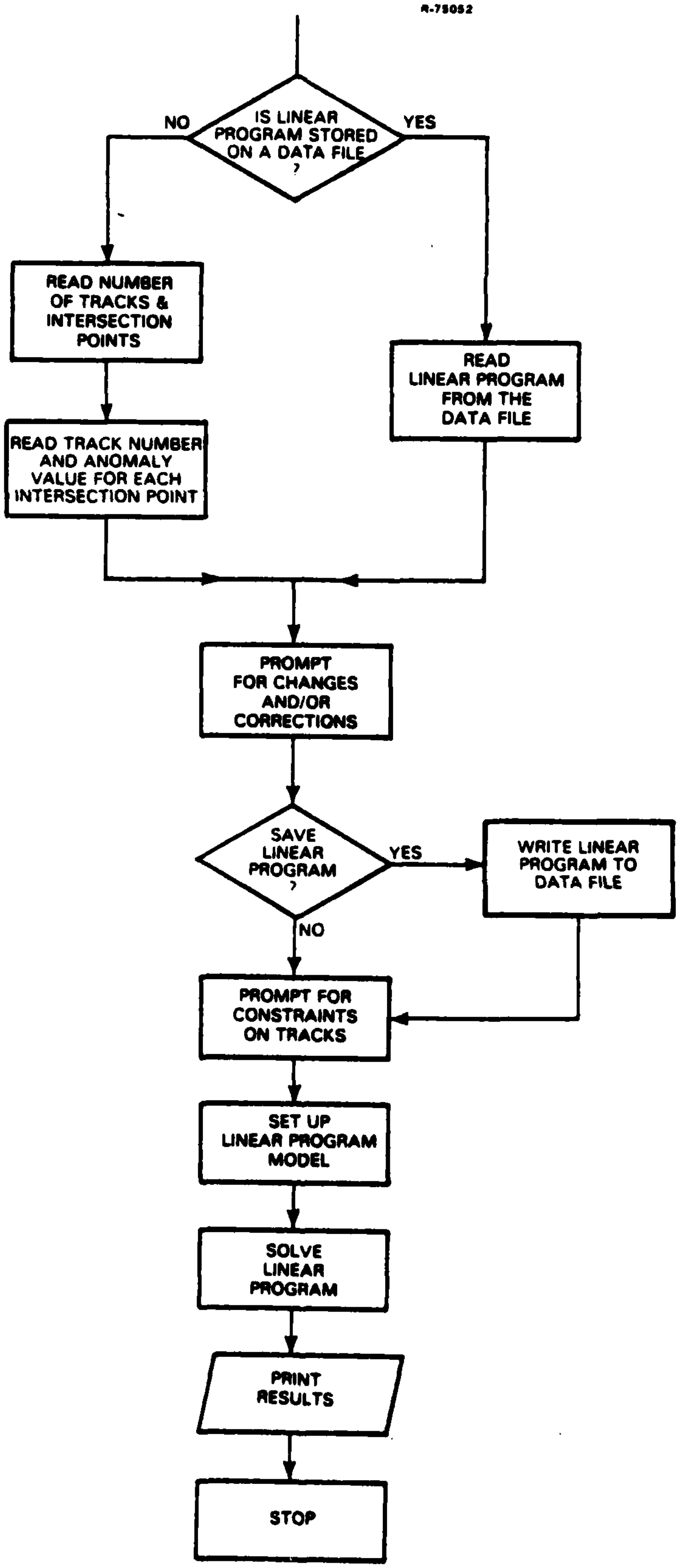

Figure 3.7-3 Logic Flowchart for Program LINPRO

point, the program will prompt the user for the track numbers of the two tracks which meet at the intersection point, along with their corresponding free-air gravity anomaly values. The program then echoes the two track numbers and their corresponding free-air gravity anomaly values for each intersection point, and prompts the user for any required changes.

Next, the user is asked whether the linear program model should be saved on a data file. If so, the user will be prompted for a file name for storing the linear programming model.

The program then prompts the user for any constraints to be imposed on the individual track adjustments. The user is prompted for a track number and a corresponding constraint value. The program echoes the track number and constraint value, and the user has the option to make any changes. The user may place constraints on several tracks, on every track, or no tracks.

The next section of the program constructs the linear program model corresponding to the track intersection points and user-imposed constraints. Reference 1 gives a full description of how the linear program model is constructed from the tracks and intersection points, but a few important programming considerations are described here. First, the actual track adjustments can be either positive or negative. But, for the linear program, the variables must be nonnegative. Hence, for each track adjustment, two dummy variables must be created and the following substitution must be made:

$$A_i = B_i - C_i \qquad (3.7\text{-}2)$$

where

$$A_i = \text{adjustment term for track i}$$

$$B_i, C_i = \text{dummy variables}$$

So, each track will result in two variables in the linear programming model.

As was stated earlier, the user-imposed constraints are given in the following form:

$$|A_i| \leq C \qquad (3.7\text{-}3)$$

where

$$A_i = \text{adjustment term for track i}$$

$$C = \text{constraint value } (\geq 0)$$

Equation 3.7-3 can be transformed into the following two inequalities:

$$A_i \leq C \qquad (3.7\text{-}4)$$

$$-A_i \leq C \qquad (3.7\text{-}5)$$

These two equations are in the linear programming format. Hence, each track constraint will result in two equations in the linear programming model.

Since each intersection point will give rise to two equations in the linear programming model (see Ref. 1), the size of the linear program model associated with the adjustment of a set of ocean tracks can be expressed as:

$$N = 2T + 1 \tag{3.7-6}$$

$$M = 2(I + C) \tag{3.7-7}$$

where

N = number of unknowns

M = number of equations

T = number of tracks

I = number of intersection points

C = number of imposed constraints

Once the linear program model is constructed, it is solved using the IMSL subroutine ZX3LP. The solution that is returned from this subroutine contains the dummy variables which were used to represent the track adjustments. Hence, Eq. 3.7-2 must be used to solve for the actual track adjustments.

LIST OF SUBROUTINES

ZX3LP	IMSL routine to solve the linear programming model
NEWINTER	Prompt user for track numbers and anomaly values at intersection points
INPCHR	System utility routine used to prompt for character string input
YESNO	Check for a YES or NO answer
HALT	Stop program execution

3.8 UPPER LEVEL SUBROUTINES

3.8.1 Subroutine AVER

CALLING SEQUENCE: AVER(X,Y,Z,NALL,I,J,IX,IY,XAXIS,YAXIS,GRID)

FUNCTION: Main routine for gridding algorithm. Computes the value at a grid point by a weighted average of data points near the grid point.

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	Longitude values of points
Y	R*4	(*)	Input	Latitude values of points
Z	R*4	(*)	Input	Data values to be gridded
NALL	I*4	-	Input	Number of points
I	I*4	-	Input	X position of current grid point
J	I*4	-	Input	Y position of current grid point
IX	I*4	-	Input	Number of grid points in longitude direction
IY	I*4	-	Input	Number of grid points in latitude direction
XAXIS	R*4	(*)	Input	Longitude coordinates of grid points
YAXIS	R*4	(*)	Input	Latitude coordinates of grid points
GRID	R*4	-	Output	Value at the grid point

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: PLUCK

3.8.2 Subroutine ECDFPLOT

CALLING SEQUENCE: ECDFPLOT(X,N,TITLE,XP,YP,LINK,NP,ZAP)

FUNCTION: To construct an ECDF plot

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	Data points to be plotted
N	I*4	-	Input	Number of points
TITLE	CHAR	-	Input	Title for plot
XP	R*4	(*)	Output	X coordinates of plotted points
YP	R*4	(*)	Output	Y coordinates of plotted points
LINK	I*4	(*)	Output	Indices of plotted points
NP	I*4	-	Output	Number of plotted points
ZAP	I*4	(*)	Input	List of points not to be plotted

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: VSRTR,DISPLA,ANOTAT,AGSETF,EZXY,PWRY

3.8.3 Subroutine FINDINTER

CALLING SEQUENCE: FINDINTER(XIN,YIN,LONMIN,LONMAX,RLON,RLAT)

FUNCTION: To determine the latitude and longitude coordinates of the track intersection point marked by the cursor

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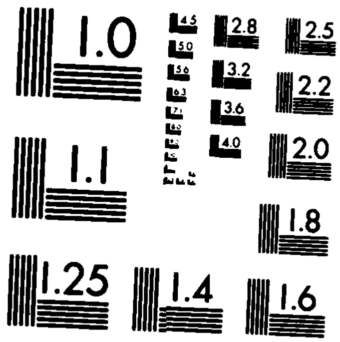

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
XIN	R*4	-	Input	X coordinate of cursor
YIN	R*4	-	Input	Y coordinate of cursor
LONMIN	R*4	-	Input	Minimum longitude of plotted region
LONMAX	R*4	-	Input	Maximum longitude of plotted region
RLON	R*4	-	Output	Intersection point longitude
RLAT	R*4	-	Output	Intersection point latitude

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: GETSET

3.8.4 Subroutine FINDPT

CALLING SEQUENCE: FINDPT(X,Y,N,XF,YF,INDEX)

FUNCTION: To select the point on the gravity file closest to the position marked by the cursor

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	X coordinates of plotted points
Y	R*4	(*)	Input	Y Coordinates of plotted points

N	I*4	-	Input	Number of plotted points
XF	R*4	-	Input	X coordinate of cursor
YF	R*4	-	Input	Y coordinate of cursor
INDEX	I*4	(*)	Output	Index of selected point

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: *NONE*

3.8.5 Subroutine FINDSQ

CALLING SEQUENCE: FINDSQ(X,Y,N,X1,Y1,X2,Y2,EPS,K,INDEX)

FUNCTION: To select all points in the gravity file which lie within a rectangular region

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	X coordinates of plotted points
Y	R*4	(*)	Input	Y coordinates of plotted points
N	I*4	-	Input	Number of plotted points
X1,Y1	R*4	-	Input	Coordinates of one corner of the rectangular region
X2,Y2	R*4	-	Input	Coordinates of opposite corner of the rectangular region
EPS	R*4	-	Input	Tolerance parameter
K	I*4	-	Output	Number of selected points
INDEX	I*4	(*)	Output	Index of selected points

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: *NONE*

3.8.6 Subroutine FINDTRK

CALLING SEQUENCE: FINDTRK(X,Y,N,X1,Y1,X2,Y2,EPS,K,INDEX)

FUNCTION: To select all the points in the gravity file which lie along a straight line track marked by the cursor

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	X coordinates of plotted points
Y	R*4	(*)	Input	Y coordinates of plotted points
N	I*4	-	Input	Number of plotted points
X1	R*4	-	Input	X coordinate of track starting point
Y1	R*4	-	Input	Y coordinate of track starting point
X2	R*4	-	Input	X coordinate of track stopping point
Y2	R*4	-	Input	X coordinate of track stopping point
EPS	R*4	-	Input	Tolerance value
K	I*4	-	Output	Number of selected points
INDEX	I*4	(*)	Output	Index of selected points

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: *NONE*

3.8.7 Subroutine QQPLOT

CALLING SEQUENCE: QQPLOT(X,N,TITLE,XP,YP,LINK,NP,ZAP)

FUNCTION: To construct a QQ plot

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
X	R*4	(*)	Input	Data values to be plotted
N	I*4	-	Input	Number of points
TITLE	CHAR	-	Input	Title for plot
XP	R*4	(*)	Output	X coordinates of plotted points
YP	R*4	(*)	Output	Y coordinates of plotted points
LINK	I*4	(*)	Output	Indices of plotted points
NP	I*4	-	Output	Number of plotted points
ZAP	I*4	(*)	Input	List of points not to be plotted

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: VSRTR,MDNRIS,DISPLA,ANOTAT,AGSETF, EZXY,PWRY

3.8.8 Subroutine ROBUST

CALLING SEQUENCE: ROBUST(VECTOR,LENGTH)

FUNCTION: This subroutine is the main controller routine for the robust estimator section

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
VECTOR	R*4	(*)	Input	Data points for processing robust estimators
LENGTH	I*4	-	Input	Number of data points

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: MEAN, MEDIAN, STDEV, MEST, SINEST, HLEST, TRIMMED, BIWEIGHT, BHEST, FLATLABS, PRTHELP, VTSCROLL, INPRL4, INPIN4, QUARTILE

3.8.9 Subroutine ZOOM

CALLING SEQUENCE: ZOOM(XOFF,YOFF,IP)

FUNCTION: To control the zoom and scroll features of the graphics terminal. This routine serves as an interface between the user and the calls to the Lexidata library for zoom and scroll.

ARGUMENTS:

NAME	TYPE	DIMENSION	IN/OUT	DESCRIPTION
XOFF	I*2	-	Output	X coordinate of scrolled origin
YOFF	I*2	-	Output	Y coordinate of scrolled origin
IP	I*2	-	Output	Zoom factor

COMMON BLOCKS: *NONE*

SUBPROGRAMS CALLED: DSCER,DSCXY,DSZOM,WAIT,DSGXY,HOLD,INPIN2 HALT

3.9 SUMMARY OF ALGORITHMS

This section of the report will describe the mathematical algorithms implemented by some of the subroutines of the gravity data evaluation software.

3.9.1 Gridding Algorithm (Subroutine AVER)

As was stated earlier, the contour plot program and the surface plot program both accept unevenly spaced data. However, the system plot routines which actually construct the plots require a rectangular grid of data. Hence, the unevenly spaced input data points must be gridded to an evenly spaced rectangular grid.

The gridding algorithm implemented for the gravity data evaluation software is based on a weighted average method. At each grid point, a search region is established, extending for one grid interval in every direction. If the number of points within the search region is equal to or less than 100, then all points within the search region are selected. If the number of points is greater than 100, only the first 100 points in the input file are selected. In case no points are found within the search region, the search interval is increased to two grid intervals, and this process of increasing the search interval (by one unit at a time) is repeated, if necessary, until at least one point has been selected. The value then assigned to the grid point is given by:

$$Z = \frac{\sum_{i=1}^{N} Z_i / d_i^2}{\sum_{i=1}^{N} 1 / d_i^2} \qquad (3.9\text{-}1)$$

where

N = number of selected points

Z_i = value of i^{th} selected point

d_i = distance from the grid point to the i^{th} selected point

The distance between the grid point and the data points is calculated using a flat-earth approximation formula. That is, given two points, A and B, with latitude and longitude coordinates (ϕ_A, λ_A) and (ϕ_B, λ_B), respectively, the distance between A and B is given by

$$D = R_e\ (^{\pi}/180)\ [(\Delta\phi)^2 + \cos^2\phi_A(\Delta\lambda)^2]^{1/2} \qquad (3.9\text{-}2)$$

where

R_e = radius of earth 6378.135 km

$^{\pi}/180$ = conversion factor, degrees to radians 0.017453293

$\Delta\lambda = \lambda_A - \lambda_B$

$\Delta\phi = \phi_A - \phi_B$

3.9.2 Convert Zoomed Cursor Coordinates to Original Coordinates (Subroutine CONZOOM)

When the zoom and scroll option is invoked, the plot on the graphics terminal undergoes two transformations. First, scrolling the plot causes the origin of the plot (i.e., the upper left corner) to change from (0,0) to a new value. Selecting the zoom option will cause a change in scale in both the x-axis and y-axis directions. When the cursor is invoked and points on the plot are selected, the coordinates of the cursor in the zoomed reference frame must be converted to

coordinates in the original plot reference frame. This conversion is given by the following equations:

$$IX_o = XOFF + INT(IX_Z/IP) \tag{3.9-3}$$

$$IY_o = YOFF + INT(IY_Z/IP) \tag{3.9-4}$$

where

IX_Z, IY_Z = x and y coordinates of the cursor in the zoomed reference frame

IX_o, IY_o = x and y coordinates of the cursor in the original reference frame

XOFF, YOFF = origin of plot

IP = zoom factor

INT() = greatest integer function

3.9.3 Convert Plotter Coordinates to User Coordinates (Subroutine CONUSER)

When the position of the cursor is determined by calling the Lexidata routine DSGXY, the returned values are in plotter coordinates. That means that the x coordinate is an integer between 0 and 1279, and the y coordinate is an integer between 0 and 1023. To find the points selected by the cursor, the plotter coordinates must be converted to the coordinate system in which the plot was produced. This is called the user coordinate system. Assume that the limits of the plot are given by MXA, MXB, MYA, and MYB in plotter coordinates, and XC, XD, YC, and YD in user coordinates. These limits are obtained by calling the system plot routine GETSET. Then, the conversion from plotter coordinates to user coordinates is given by:

$$IX_U = XD + \frac{XD - XC}{MXB - MXA} (IX_P - MXB) \qquad (3.9\text{-}5)$$

$$IY_U = YD + \frac{YD - YC}{MYB - MYA} (IY_P - MYB) \qquad (3.9\text{-}6)$$

where

IX_U, IY_U = coordinates in the user reference frame

IX_P, IY_P = coordinates in the plotter reference frame

3.9.4 Find Point Closest to the Cursor (Subroutine FINDPT)

If the cursor is located at (XCURS, YCURS) in the user coordinate frame, then the point closest to the cursor is the point that minimizes:

$$D = (X - XCURS)^2 + (Y - YCURS)^2 \qquad (3.9\text{-}7)$$

where

X,Y = coordinates in user reference frame of the plotted points

3.9.5 Find All Points within a Rectangular Region (Subroutine FINDSQ)

If the coordinates of two opposite corners of the rectangular region are given by (XMIN, YMIN) and (XMAX, YMAX), then all points which satisfy the following inequalities will be selected:

$$XMIN \leq X \leq XMAX \qquad (3.9\text{-}8)$$

$$YMIN \leq Y \leq YMAX \qquad (3.9\text{-}9)$$

where

X,Y = coordinates in user reference frame of the plotted points

3.9.6 Find All Points Along a Track (Subroutine FINDTRK)

A track is determined by a starting point (X1, Y1) and a stopping point (X2, Y2). A straight line can then be drawn through these two points. The distance between a point and this line is given by:

$$D = \frac{|SX - Y + B|}{[S^2 + 1]^{1/2}} \qquad (3.9\text{-}10)$$

where

X,Y = coordinates in user reference frame of the plotted points

S = slope of line

$= (Y2 - Y1)/(X2 - X1)$

B = intercept of line

$= Y1 - SX1$

A point is first checked to see whether it lies within the starting and stopping points of the line. If it does, the distance from the point to the line is calculated using the above formula. If the distance is less than a given tolerance value, the point is selected.

3.9.7 Determine Latitude-Longitude Coordinates of an Intersection Point (Subroutine FINDINTER)

An intersection point is identified on the graphics terminal using the cursor. The coordinates of the cursor, say

(U,V), are given in the user coordinate frame. The user coordinate frame is not in terms of latitude and longitude, but is given in map projection units. For the scatter plot program, a Mercator projection is used in constructing the plot. Hence, to convert (U,V) to latitude-longitude coordinates, the following equations must be solved:

$$LON = b\,U \tag{3.9-11}$$

$$LAT = 2\tan^{-1}\left[e^{V/b}\right] - \frac{\pi}{2} \tag{3.9-12}$$

where

LAT, LON = latitude-longitude coordinates of the intersection point

U, V = coordinates of the intersection point in map projection units

b = map scale factor

It is important to note that this routine will function correctly only when the Mercator projection is used. If the scatter plot program is modified to allow for other map projections, this routine will also have to be modified.

3.9.8 Robust Estimators (Subroutine ROBUST)

The robust estimators are implementations of the algorithms found in Refs. 5 and 6. The iterative M-estimate and sine-estimate use a modified Newton's method with only 25 iterations allowed. The convergence criterion is satisfied when the current solution differs from the last by less than 0.1 percent of the median.

The Hodges-Lehmann estimate of a set of data:

$$X_1, X_2, \ldots . X_N$$

is the median of the ordered set containing as elements

$$(X_I + X_J)/2.0 \qquad I=1,2,\ldots,N; \quad J=1,2,\ldots,N$$

Since for a given pair (I,J) and (J,I), where I is unequal to J, the resultant means are the same, only one is stored (to save space), but the algorithm treats this mean as though it were present twice.

4. SUMMARY

The gravity data evaluation programs were written by TASC for the Defense Mapping Agency as part of the Weapons Support System. Their purpose is to assist the evaluator in the various tasks involved in the evaluation of gravity survey data.

The gravity data evaluation programs are run interactively from one of the VT100 terminals. Many of the programs make extensive use of the Lexidata graphics terminal and interactive cursor. These plots provide the evaluator with a quick-look capability for making rapid decisions concerning the data set.

This report describes in detail the necessary inputs for running the gravity data evaluation programs, and documents the organization, structures, and algorithms for each of the programs.

REFERENCES

1. Brammer, R.F., LeSchack, A.R., and Ofenstein, W.T., "Gravity Data Evaluation Analysis and the Phase-Zero Definition of the Physical Geodesy System;" Technical Report TR-1104-1, The Analytic Sciences Corporation; Reading, Massachusetts; April 1978.

2. Brammer, R.F., LeSchack, A.R., and Ofenstein, W.T., "Gravity Data Evaluation Analysis and Software Design Plan for the Physical Geodesy System;" Technical Report TR-1240-1; The Analytic Sciences Corporation, Reading, Massachusetts; December 1978.

3. Tang, M.R., "TASC Graphics Software Package Reference Manual;" Technical Report TR-1946-6; The Analytic Sciences Corporation; Reading, Massachusetts; July 1981.

4. "Lexidata Sytem 3400 Image and Graphics Processor User Manual;" Lexidate Corporation; 1979.

5. Andrews, D.F., et al.; Robust Estimates of Location, Princeton University Press, 1972.

6. Capp, D.W., "Estimation of Mean Gravity Anomalies," Interoffice Memorandum;" IOM-DWC-78-1; The Analytic Sciences Corporation; Reading, Massachusetts; August 1978.

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